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ART. XLV.—*Jurassic Birds and their Allies;* by Professor O. C. MARSH.

[Read before Section D., British Association for the Advancement of Science, at York, Sept. 2d, 1881.]

ABOUT twenty years ago, two fossil animals of great interest were found in the lithographic slates of Bavaria. One was the skeleton of *Archæopteryx*, now in the British Museum, and the other was the *Compsognathus* preserved in the Royal Museum at Munich. A single feather, to which the name *Archæopteryx* was first applied by Von Meyer, had previously been discovered at the same locality. More recently, another skeleton has been brought to light in the same beds, and is now in the Museum of Berlin. These three specimens of *Archæopteryx* are the only remains of this genus known, while of *Compsognathus* the original skeleton is, up to the present time, the only representative.

When these two animals were first discovered, they were both considered to be reptiles by Wagner, who described *Compsognathus*, and this view has been held by various authors down to the present time. The best authorities, however, now agree with Owen that *Archæopteryx* is a bird, and that *Compsognathus*, as Gegenbaur and Huxley have shown, is a Dinosaurian reptile.

Having been engaged for several years in the investigation of American Mesozoic birds, it became important for me to study the European forms, and I have recently examined with

some care the three known specimens of *Archæopteryx*. I have also studied in the Continental Museums various fossil reptiles, including *Compsognathus*, which promised to throw light on the early forms of birds.

During my investigation of *Archæopteryx*, I observed several characters of importance not previously determined, and I have thought it might be appropriate to present them here. The more important of these characters are as follows:—

1. The presence of true teeth, in position, in the skull.
2. Vertebræ biconcave.
3. A well-ossified, broad sternum.
4. Three digits only in the manus, all with claws.
5. Pelvic bones separate.
6. The distal end of fibula in front of tibia.
7. Metatarsals separate, or imperfectly united.

These characters, taken in connection with the free metacarpals, and long tail, previously described, show clearly that we have in *Archæopteryx* a most remarkable form, which, if a bird, as I believe, is certainly the most reptilian of birds.

If now we examine these various characters in detail, their importance will be apparent.

The teeth actually in position in the skull appear to be in the premaxillary, as they are below or in front of the nasal aperture. The form of the teeth, both crown and root, is very similar to the teeth of *Hesperornis*. The fact that some teeth are scattered about near the jaw would suggest that they were implanted in a groove. No teeth are known from the lower jaw, but they were probably present.

The presacral vertebræ are all, or nearly all, biconcave, resembling those of *Ichthyornis* in general form, but without the large lateral foramina. There appear to be twenty-one presacral vertebræ, and the same, or nearly the same, number of caudals. The sacral vertebræ are fewer in number than in any known bird, those united together not exceeding five, and probably less.

The scapular arch strongly resembles that of modern birds. The articulation of the scapula and coracoid, and the latter with the sternum is characteristic; and the furculum is distinctly avian. The sternum is a single broad plate, well ossified. It probably supported a keel, but this is not exposed in the known specimens.

In the wing itself the main interest centers in the manus and its free metacarpals. In form and position these three bones are just what may be seen in some young birds of to-day. This is an important point, as it has been claimed that the hand of *Archæopteryx* is not at all avian, but reptilian. The

bones of the reptile are indeed there, but they have already received the stamp of the bird.

One of the most interesting points determined during my investigation of *Archæopteryx* was the separate condition of the pelvic bones. In all other known adult birds, recent and extinct, the three pelvic elements, ilium, ischium and pubis, are firmly anchylosed. In young birds these bones are separate, and in all known Dinosaurian reptiles they are also distinct. This point may perhaps be made clearer by referring to the two diagrams before you, which I owe to the kindness of my friend Dr. Woodward, of the British Museum, who also gave me excellent facilities for examining the *Archæopteryx* under his care. In the first diagram we have represented the pelvis of an American Jurassic Dinosaur allied to *Iguanodon*, and here the pelvic bones are distinct. The second diagram is an enlarged view of the pelvis of the *Archæopteryx* in the British Museum, and here too the ilium is seen separate from the ischium and pubis.

In birds the fibula is usually incomplete below, but it may be coössified with the side of the tibia. In the typical Dinosaurs, *Iguanodon*, for example, the fibula at its distal end stands in front of the tibia, and this is exactly its position in *Archæopteryx*, an interesting point not before seen in birds.

The metatarsal bones of *Archæopteryx* show, on the outer face at least, deep grooves between the three elements, which imply that the latter are distinct, or unite late together. The free metacarpal and separate pelvic bones would also suggest distinct metatarsals, although they naturally would be placed closely together, so as to appear connate.

Among other points of interest in *Archæopteryx* may be mentioned the brain-cast, which shows that the brain, although comparatively small, was like that of a bird, and not that of a Dinosaurian reptile. It resembles in form the brain-cast of *Laopteryx*, an American Jurassic bird, which I have recently described. The brain of both these birds appears to have been of a somewhat higher grade than that of *Hesperornis*, but this may have been due to the fact that the latter was an aquatic form, while the Jurassic species were land birds.

As the *Dinosauria* are now generally considered the nearest allies to birds, it was interesting to find in those investigated many points of resemblance to the latter class. *Compsognathus*, for example, shows in its extremities a striking similarity to *Archæopteryx*. The three clawed digits of the manus correspond closely with those of that genus; although the bones are of different proportions. The hind feet also have essentially the same structure in both. The vertebræ, however, and the pelvic bones of *Compsognathus* differ materially from those of *Archæ-*

opteryx, and the two forms are in reality widely separated. While examining the *Compsognathus* skeleton, I detected in the abdominal cavity the remains of a small reptile which had not been previously observed. The size and position of this inclosed skeleton would imply that it was a fœtus; but it may possibly have been the young of the same species, or an allied form, that had been swallowed. No similar instance is known among the Dinosaurs.

A point of resemblance of some importance between birds and Dinosaurs is the clavicle. All birds have those bones, but they have been considered wanting in Dinosaurs. Two specimens of *Iguanodon*, in the British Museum, however, show that these elements of the pectoral arch were present in that genus, and in a diagram before you one of these bones is represented. Some other *Dinosauria* possess clavicles, but in several families of this subclass, as I regard it, they appear to be wanting.

The nearest approach to birds now known would seem to be in the very small Dinosaurs from the American Jurassic. In some of these, the separate bones of the skeleton cannot be distinguished with certainty from those of Jurassic birds, if the skull is wanting, and even in this part the resemblance is striking. Some of these diminutive Dinosaurs were perhaps arboreal in habit, and the difference between them and the birds that lived with them may have been at first mainly one of feathers, as I have shown in my Memoir on the *Odontornithes*, published during the past year.

It is an interesting fact that all the Jurassic birds known, both from Europe and America, are land birds, while all from the Cretaceous are aquatic forms. The four oldest known birds, moreover, differ more widely from each other than do any two recent birds. These facts show that we may hope for most important discoveries in the future, especially from the Triassic, which has as yet furnished no authentic trace of birds. For the primitive forms of this class we must evidently look to the Paleozoic.

ART. XLVI.—*On the Remarkable Aurora of September* 12–13, 1881; by J. M. SCHAEBERLE.

THE night of Sept. 12–13, 1881, witnessed one of the grandest displays of aurora ever seen in this latitude. Beginning soon after sunset and lasting until the approach of day, the various phenomena which presented themselves during this time are deserving of being placed on permanent record.

The following are some of the notes taken during the night:

$7^h\ 30^m$—Ann Arbor, mean time. A grand continuous arch seen spanning the northeastern sky, beginning in the horizon at E. 1° N., and ending N. 45° W.; altitude of highest point of arch 30°; breadth, 5° (close resemblance to cirrus clouds). A second arch, enclosed by the first and 10° from it, quite bright. Space between the arches clear as any part of the sky.

$7^h\ 35^m$. At the eastern extremity of the large arc are streamers inclined 70° to the horizon.

$7^h\ 37^m$. Four bright streamers in the east, 15° long, $1\frac{1}{2}$° wide, and 2° from each other.

$7^h\ 41^m$. Bright streamer, 40° long, $1\frac{1}{2}$° broad, E. 10° N. Bright auroral light in northern horizon; most intense, N. 40° E.

$7^h\ 42^m$. Broad sheet of streamers in the east; horizontal motion from east to west, very marked; rate, 1° in 8 seconds of time. Large arch has disappeared.

$7^h\ 50^m$. Dark segment; greatest altitude 3°, at N. 20° E. α Aurigæ seen through the same with undiminished luster.

$7^h\ 56^m$. Streamers 5° long between N. 30° W., and N. 70° E. It is very evident that the dark segment is nothing but the clear sky, for occasionally a streamer starts from the very horizon and in moving west the dark space seems to offer no resistance.

$8^h\ 2^m$. Streamers 15° long; a detached one in Cassiopeia, 45° from the horizon, seen moving westward at the rate of 1° in 3 seconds.

$8^h\ 5^m$. Dark segment 5° high; streamers form one continuous sheet of light. In the northeast streamers start 2° from horizon and in their motion westward plough through the dark space.

8^h, 12^m–20^m. Bright arch from N. 30° W. to N. 60° E.; greatest elevation, 10°; occasional streamers, from 3° to 5° in length, shooting from it. Electric lightning in the east.

$8^h\ 31^m$. Streamers in the north 15° long; dark segment 6° high, but very irregular in outline.

$8^h\ 33^m$. Continuous sheet of light in N.N.E.; no arch.

$11^h\ 45^m$. Up to the present time only the auroral twilight could be seen. Moon about three hours high; signs of returning activity; dark segment 7° high.

$11^h\ 53^m$. Bright streamer 40° long, N. 10° E.

$11^h\ 54^m$. Three arches; whole northern sky covered with streamers 45° in length.

$11^h\ 56^m$. Streamers of a reddish tinge, 55° in length; arch broken near the north point; western portion wanting.

$12^h\ 0^m$. Arch 15° high, symmetrical with respect to the meridian. Irregular black patches distributed throughout the space enclosed by the arch; sky in the northwest has a reddish tinge. Motion from east to west, 1° in 3 seconds.

$12^h\ 10^m$. Waves toward the zenith very violent; streamers 50° long.

$12^h\ 13^m$–17^m. Whole northern sky up to 45° altitude, in great commotion; streamers 60° long.

$12^h\ 30^m$–60^m. Streamers from the east and west points of horizon meet south of the zenith, within the square of Pegasus, several parallel spans formed and broken at short intervals.

13^h. Streamers extend 15° southeast of the point of convergence, which is now near α Andromedæ.

$13^h\ 20^m$. Arch from east to west, altitude 25°; vigorous action of auroral waves.

$13^h\ 30^m$. The crossing of the streamers in the zenith gives the appearance of a zigzag motion.

$13^h\ 30^m$. Point of convergence near δ Andromedæ.

$13^h\ 41^m$. Remarkable streamer E. 30° N., beginning in the horizon and for a distance of 8° making an angle of only 30° with it, then suddenly changing its direction to parallelism with the other streamers each side of it which are inclined 75° to the horizon.

$13^h\ 55^m$. Sudden abatement of vigorous action; looks as though the display was coming to a close.

$14^h\ 2^m$. Two arches formed, one in the N.E. the other in the N.N.W., joining each other in the horizon 15° east of north point.

Observations resumed at $15^h\ 45^m$. The view now presented to the observer baffles all description. The whole northern sky from N. 55 W., to N. 55 E. and from the horizon to 60° altitude is one mass of moving fire. The auroral waves succeed each other with great rapidity. Each wave extends throughout the entire width of the aurora, and the flashes toward the zenith are in the form of segments of small circles or zones parallel to the horizon. In the northeast the phenomenon known as the *merry dancers* is very beautiful. A little to the west of north sudden outbursts of light, similar to sheet lightning and having the form of cumulus clouds, instantly appear and disappear at short intervals.

This description can give but a faint idea of the appearance of the aurora at the close of my observations. Athough the moon was still two days from last quarter the phenomena were seen with a vividness truly remarkable. On the following evening the auroral twilight was quite bright until the moon came up. An arch was formed and broken several times. About nine o'clock the northern sky had the appearance of being covered with faint streamers 40° long. Later the aurora gradually died out, and by eleven o'clock no trace of it could be seen.

ART. XLVII.—*Address of Sir John Lubbock, President of the British Association at York.*

[Continued from page 289.]

* * IN Astronomy, the discovery in 1845 of the planet Neptune, made independently and almost simultaneously by Adams and by Le Verrier, was certainly one of the greatest triumphs of mathematical genius. Of the minor planets four only were known in 1831, whilst the number now on the roll amounts to 220. Many astronomers believe in the existence of an intra-mercurial planet or planets, but this is still an open question. The Solar System has also been enriched by the discovery of an inner ring to Saturn, of satellites to Mars, and of additional satellites to Saturn, Uranus and Neptune.

The most unexpected progress, however, in our astronomical knowledge during the past half-century has been due to spectrum analysis.

The dark lines in the spectrum were first seen by Wollaston, who noticed a few of them; but they were independently discovered by Fraunhofer, after whom they are justly named, and who, in 1814, mapped no fewer than 576. The first steps in "spectrum analysis," properly so called, were made by Sir J. Herschel, Fox Talbot, and by Wheatstone, in a paper read before this Association in 1835. The latter showed that the spectrum emitted by the incandescent vapor of metals was formed of bright lines, and that these lines, while, as he then supposed, constant for each metal, differed for different metals. "We have here," he said, "a mode of discriminating metallic bodies more readily than that of chemical examination, and which may hereafter be employed for useful purposes." Nay, not only can bodies thus be more readily discriminated, but, as we now know, the presence of extremely minute portions can be detected, the $\frac{1}{5000000}$th part of a grain being in some cases easily perceptible. It is also easy to see that the presence of any new simple substance might be detected, and in this manner already several new elements have been discovered.

But spectrum analysis has led to even grander and more unexpected triumphs. Fraunhofer himself noticed the coincidence between the double dark line D of the solar spectrum and a double line which he observed in the spectra of ordinary flames, while Stokes pointed out to Sir W. Thompson, who taught it in his lectures, that in both cases these lines were due to the presence of sodium. To Kirchhoff and Bunsen, however, is due the independent conception and the credit of having first systematically investigated the relation which exists between Fraunhofer's lines and the bright lines in the spectra of incan-

descent metals. In order to get some fixed measure by which they might determine and record the lines characterizing any given substance, it occurred to them that they might use for comparison the spectrum of the sun. They accordingly arranged their spectroscope so that one-half of the slit was lighted by the sun, and the other by the luminous gases they proposed to examine. It immediately struck them that the bright lines in the one corresponded with the dark lines in the other—the bright line of sodium, for instance, with the line or rather lines D in the sun's spectrum. The conclusion was obvious. There was sodium in the sun! It must indeed have been a glorious moment when that thought flashed across them, and even by itself well worth all their labor.

But why is the bright line of a sodium flame represented by a black one in the spectrum of the sun? To Ångström is due the theory that a vapor of gas can absorb luminous rays of the same refrangibility only which it emits when highly heated; while Balfour Stewart independently discovered the same law with reference to radiant heat.

This is the basis of Kirchhoff's theory of the origin of Fraunhofer's lines. In the atmosphere of the sun the vapors of various metals are present, each of which would give its characteristic lines, but within this atmospheric envelope is the still more intensely heated nucleus of the sun, which emits a brilliant continuous spectrum, containing rays of all degrees of refrangibility. When the light of this intensely heated nucleus is transmitted through the surrounding atmosphere, the bright lines which would be produced by this atmosphere are seen as dark ones.

Kirchhoff and Bunsen thus proved the existence in the sun of hydrogen, sodium, magnesium, calcium, iron, nickel, chromium, manganese, titanium and cobalt; since which Ångström, Thalen and Lockyer have considerably increased the list.

But it is not merely the chemistry of the heavenly bodies on which light is thrown by the spectroscope; their physical structure and evolutional history are also illuminated by this wonderful instrument of research.

It used to be supposed that the sun was a dark body enveloped in a luminous atmosphere. The reverse now appears to be the truth. The body of the sun, or photosphere, is intensely brilliant; round it lies the solar atmosphere of comparatively cool gases, which cause the dark lines in the spectrum; thirdly, a chromosphere,—a sphere principally of hydrogen, jets of which are said sometimes to reach to a height of 100,000 miles or more, into the outer coating or corona, the nature of which is still very doubtful.

Formerly the red flames which represent the higher regions

of the chromosphere could be seen only on the rare occasions of a total solar eclipse. Janssen and Lockyer, by the application of the spectroscope, have enabled us to study this region of the sun at all times.

It is, moreover, obvious that the powerful engine of investigation afforded us by the spectroscope is by no means confined to the substances which form part of our system. The incandescent body can thus be examined, no matter how great its distance, so long only as the light is strong enough. That this method was theoretically applied to the light of the stars was indeed obvious, but the practical difficulties were very great. Sirius, the brightest of all, is, in round numbers, a hundred millions of millions of miles from us; and, though as big as sixty of our suns, his light when it reaches us after a journey of sixteen years, is at most one two-thousand-millionth part as bright. Nevertheless as long ago as 1815 Fraunhofer recognized the fixed lines in the light of four of the stars, and in 1863 Miller and Huggins in our own country, and Rutherfurd in America, succeeded in determining the dark lines in the spectrum of some of the brighter stars, thus showing that these beautiful and mysterious lights contain many of the material substances with which we are familiar. In Aldebaran, for instance, we may infer the presence of hydrogen, sodium, magnesium, iron, calcium, tellurium, antimony, bismuth, and mercury; some of which are not yet known to occur in the sun. As might have been expected the composition of the stars is not uniform, and it would appear that they may be arranged in a few well marked classes, indicating differences of temperature, or in other words of age. Some recent photographic spectra of stars obtained by Huggins go very far to justify this view.

Thus we can make the stars teach us their own composition with light which started from its source before we were born—light older than our Association itself.

Until 1864, the true nature of the unresolved nebulæ was a matter of doubt. In that year, however, Huggins turned his spectroscope on to a nebula, and made the unexpected discovery that the spectra of some of these bodies are discontinuous—that is to say, consist of bright lines only, indicating that "in place of an incandescent solid or liquid body we must probably regard these objects, or at least their photo-surfaces, as enormous masses of luminous gas or vapor. For it is from matter in a gaseous state only that such light as that of the nebulæ is known to be emitted." So far as observation has yet gone, nebulæ may be divided into two classes: some giving a continuous spectrum, others one consisting of bright lines. These latter all appear to give essentially the same spectrum, consisting of a few bright lines. Two of them, in Mr. Huggins's

opinion, indicate the presence of hydrogen: one of them agrees in position with a line characteristic of nitrogen.

But spectrum analysis has even more than this to tell us. The old methods of observation could determine the movements of the stars so far only as they were transverse to us; they afforded no means of measuring motion either directly towards or away from us. Now Döppler suggested in 1841 that the colors of the stars would assist us in this respect, because they would be affected by their motion to and from the earth, just as a steam-whistle is raised or lowered as it approaches or recedes from us. Everyone has observed that if a train whistles as it passes us, the sound appears to alter at the moment the engine goes by. This arises, of course, not from any change in the whistle itself, but because the number of vibrations which reach the ear in a given time are increased by the speed of the train as it approaches, and diminished as it recedes. So, like the sound, the color would be affected by such a movement; but Döppler's method was practically inapplicable, because the amount of effect on the color would be utterly insensible; and even if it were otherwise the method could not be applied, because, as we did not know the true color of the stars, we have no datum line by which to measure.

A change of refrangibility of light, however, does occur in consequence of relative motion, and Huggins successfully applied the spectroscope to solve the problem. He took in the first place the spectrum of Sirius, and chose a line known as F, which is due to hydrogen. Now, if Sirius was motionless, or rather if it retained a constant distance from the earth, the line F would occupy exactly the same position in the spectrum of Sirius, as in that of the sun. On the contrary if Sirius were approaching or receding from us, this line would be slightly shifted either toward the blue or red end of the spectrum. He found that the line had moved very slightly toward the red, indicating that the distance between us and Sirius is increasing at the rate of about twenty miles a second. So also Betelgeux, Rigel, Castor and Regulus are increasing their distance; while, on the contrary, that of others, as for instance of Vega, Arcturus and Pollux, is diminishing. The results obtained by Huggins on about twenty stars have since been confirmed and extended by Mr. Christie, now Astronomer Royal, in succession to Sir G. Airy, who has long occupied the post with so much honor to himself and advantage to science.

To examine the spectrum of a shooting star would seem even more difficult; yet Alexander Herschel has succeeded in doing so, and finds that their nuclei are incandescent solid bodies: he has recognized the lines of potassium, sodium, lithium and other substances, and considers that the shooting stars are

bodies similar in character and composition to the stony masses which sometimes reach the earth as aërolites.

Some light has also been thrown upon those mysterious visitants, the comets. The researches of Prof. Newton on the periods of meteoroids led to the remarkable discovery by Schiaparelli of the identity of the orbits of some meteor-swarms with those of some comets. The similarity of orbits is too striking to be the result of chance, and shows a true cosmical relation between the bodies. Comets, in fact, are in some cases at any rate groups of meteoric stones. From the spectra of the small comets of 1866 and 1868, Huggins showed that part of their light is emitted by themselves, and reveals the presence of carbon in some form. A photographic spectrum of the comet recently visible, obtained by the same observer, is considered by him to prove that nitrogen, probably in combination with carbon, is also present.

No element has yet been found in any meteorite, which was not previously known as existing in the earth, but the phenomena which they exhibit indicate that they must have been formed under conditions very different from those which prevail on the earth's surface. I may mention, for instance, the peculiar form of crystallized silica, called by Maskelyne, Asmanite; and the whole class of meteorites, consisting of iron generally alloyed with nickel, which Daubrée terms holosiderites. The interesting discovery, however, by Nordenskiöld, in 1870, at Ovifak, of a number of blocks of iron alloyed with nickel and cobalt, in connection with basalts containing disseminated iron, has, in the words of Judd, "afforded a very important link, placing the terrestrial and extra-terrestrial rocks in closer relations with one another."

We have as yet no sufficient evidence to justify a conclusion as to whether any substances exist in the heavenly bodies which do not occur in our earth, thought there are many lines which cannot yet be satisfactorily referred to any terrestrial element. On the other hand, some substances which occur on our earth have not yet been detected in the sun's atmosphere.

Such discoveries as these seemed, not long ago, entirely beyond our hopes. M. Comte, indeed, in his "Cours de Philosophie Positive," as recently as 1842, laid it down as an axiom regarding the heavenly bodies, that "Nous concevons la possibilité de déterminer leurs formes, leurs distances, leurs grandeurs et leurs mouvements, tandis que nous ne saurions jamais étudier par aucun moyen leur composition chimique ou leur structure minéralogique." Yet within a few years what he supposed to be impossible has been actually accomplished, showing how unsafe it is to limit the possibilities of science.

It is hardly necessary to point out that, while the spectrum

has taught us so much, we have still even more to learn. Why should some substances give few, and others many, lines? Why should the same substance give different lines at different temperatures? What are the relations between the lines and the physical or chemical properties.

We may certainly look for much new knowledge of the hidden actions of atoms and molecules from future researches with the spectroscope. It may even, perhaps, teach us to modify our views of the so-called simple substances. Prout long ago, struck by the remarkable fact that nearly all atomic weights are simple multiples of the atomic weight of hydrogen, suggested that hydrogen must be the primordial substance. Brodie's researches also naturally fell in with the supposition that the so-called simple substances are in reality complex, and that their constituents occur separately in the hottest regions of the solar atmosphere. Lockyer considers that his researches lend great probability to this view. The whole subject is one of intense interest, and we may rejoice that it is occupying the attention, not only of such men as Abney, Dewar, Hartley, Liveing, Roscoe and Shuster in our own country, but also of many foreign observers.

When geology so greatly extended our ideas of past time, the continued heat of the sun became a question of greater interest than ever. Helmholtz has shown that, while adopting the nebular hypothesis, we need not assume that the nebulous matter was originally incandescent; but that its present high temperature may be, and probably is, mainly due to gravitation between its parts. It follows that the potential energy of the sun is far from exhausted, and that with continued shrinking it will continue to give out light and heat, with little, if any, diminution for several millions of years.

Like the sands of the sea, the stars of heaven have ever been used as effective symbols of number, and the improvements in our methods of observation have added fresh force to our original impressions. We now know that our earth is but a fraction of one out of at least 75,000,000 worlds.

But this is not all. In addition to the luminous heavenly bodies, we cannot doubt that there are countless others, invisible to us from their greater distance, smaller size, or feebler light; indeed we know that there are many dark bodies which now emit no light or comparatively little. Thus in the case of Procyon, the existence of an invisible body is proved by the movement of the visible star. Again I may refer to the curious phenomena presented by Algol, a bright star in the head of Medusa. This star shines without change for two days and thirteen hours; then, in three hours and a half, dwindles from a star of the second to one of the fourth magnitude; and

then, in another three and a half hours, reassumes its original brilliancy. These changes seem certainly to indicate the presence of an opaque body, which intercepts at regular intervals a part of the light emitted by Algol.

Thus the floor of heaven is not only "thick inlaid with patines of bright gold," but studded also with extinct stars; once probably as brilliant as our own sun, but now dead and cold, as Helmholtz tells us that our sun itself will be, some seventeen millions of years hence.

The connection of Astronomy with the history of our planet has been a subject of speculation and research during a great part of the half century of our existence. Sir Charles Lyell devoted some of the opening chapters of his great work to the subject. Haughton has brought his very original powers to bear on the subject of secular changes in climate, and Croll's contributions to the same subject are of great interest. Last, but not least, I must not omit to make mention of the series of massive memoirs (I am happy to say not yet nearly terminated) by George Darwin on tidal friction, and the influence of tidal action on the evolution of the solar system.

I may perhaps just mention, as regards telescopes, that the largest reflector in 1830 was Sir W. Herschel's of 4 ft., the largest at present being Lord Rosse's of 6 ft.; as regards refractors the largest then had a diameter of $11\frac{1}{4}$ in., while your fellow townsman Cooke carried the size to 25 in., and Mr. Grubb, of Dublin, has just successfully completed one of 27 in. for the Observatory of Vienna. It is remarkable that the two largest telescopes in the world should both be Irish.

The general result of astronomical researches has been thus eloquently summed up by Proctor:—"The sidereal system is altogether more complicated and more varied in structure than has hitherto been supposed; in the same region of the stellar depths coëxist stars of many orders of real magnitude; all orders of nebulæ, gaseous or stellar planetary, ring-formed, elliptical, and spiral, exist within the limits of the galaxy; and lastly, the whole system is alive with movements, the laws of which may one day be recognized, though at present they appear too complex to be understood."

We can, I think, scarcely claim the establishment of the undulatory theory of light as falling within the last fifty years: for though Brewster, in his "Report on Optics," published in our first volume, treats the question as open, and expresses himself still unconvinced, he was, I believe, almost alone in his preference for the emission theory. The phenomena of interference, in fact, left hardly any — if any — room for doubt, and the subject was finally set at rest by Foucault's celebrated

experiments in 1850. According to the undulatory theory the velocity of light ought to be greater in air than in water, while if the emission theory were correct the reverse would be the case. The velocity of light — 186,000 miles in a second — is, however, so great that, to determine its rate in air, as compared with that in water, might seem almost hopeless. The velocity in air was, nevertheless, determined by Fizeau in 1849, by means of a rapidly revolving wheel. In the following year Foucault, by means of a revolving mirror, demonstrated that the velocity of light is greater in air than in water — thus completing the evidence in favor of the undulatory theory of light.

The idea is now gaining ground, that, as maintained by Clerk-Maxwell, light itself is an electro-magnetic disturbance, the luminiferous ether being the vehicle of both light and electricity.

Wünsch, as long ago as 1792, had clearly shown that the three primary colors were red, green, and violet; but his results attracted little notice, and the general view used to be that there were seven principal colors — red, orange, yellow, green, blue, indigo and violet; four of which — namely orange, green, indigo and violet — were considered to rise from mixtures of the other three. Red, yellow and blue were therefore called the primary colors, and it was supposed that in order to produce white light these three colors must always be present.

Helmholtz, however, again showed, in 1852, that a color to our unaided eyes identical with white, was produced by combining yellow with indigo. At that time yellow was considered to be a simple color, and this, therefore, was regarded as an exception to the general rule, that a combination of three simple colors is required to produce white. Again, it was, and indeed still is, the general impression that a combination of blue and yellow makes green. This, however, is entirely a mistake. Of course we all know that yellow paint and blue paint make green paint: but this results from absorption of light by the semi-transparent solid particles of the pigments, and is not a mere mixture of the colors proceeding unaltered from the yellow and the blue particles: moreover, as can easily be shown by two sheets of colored paper and a piece of window glass, blue and yellow light, when combined, do not give a trace of green, but if pure would produce the effect of white. Green, therefore, is after all not produced by a mixture of blue and yellow. On the other hand, Clerk-Maxwell proved in 1860 that yellow could be produced by a mixture of red and green, which put an end to the pretension of yellow to be considered a primary element of color. From these and other

considerations, it would seem, therefore, that the three primary colors — if such an impression be retained — are red, green, and violet.

The existence of rays beyond the violet, though almost invisible to our eyes, had long been demonstrated by their chemical action. Stokes, however, showed in 1852 that their existence might be proved in another manner, for that there are certain substances which, when excited by them, emit light visible to our eyes. To this phenomenon he gave the name of fluorescence. At the other end of the spectrum, Abney has recently succeeded in photographing a large number of lines in the infra-red portion, the existence of which was first proved by Sir William Herschel.

From the rarity, and in many cases the entire absence, of reference to blue, in ancient literature, Geiger — adopting and extending a suggestion first thrown out by Gladstone — has maintained that, even as recently as the time of Homer, our ancestors were blue-blind. Though for my part I am unable to adopt this view, it is certainly very remarkable that neither the Rig-veda, which consists almost entirely of hymns to heaven, nor the Zendavesta, the Bible of the Parsees or fire-worshippers, nor the Old Testament, nor the Homeric poems, ever allude to the sky as blue.

On the other hand, from the dawn of poetry, the splendors of the morning and evening skies have excited the admiration of mankind. As Ruskin says, in language almost as brilliant as the sky itself, the whole heaven, "from the zenith to the horizon, becomes one molten, mantling sea of color and fire; every black bar turns into massy gold, every ripple and wave into unsullied shadowless crimson, and purple, and scarlet, and colors for which there are no words in language, and no ideas in the mind—things which can only be conceived while they are visible; the intense hollow blue of the upper sky melting through it all, showing here deep, and pure, and lightness; there, modulated by the filmy, formless body of the transparent vapor, till it is lost imperceptibly in its crimson and gold."

But what is the explanation of these gorgeous colors? why is the sky blue? and why are the sunrise and sunset crimson and gold? It may be said that the air is blue, but if so how can the clouds assume their varied tints? Brücke showed that very minute particles suspended in water are blue by reflected light. Tyndall has taught us that the blue of the sky is due to the reflection of the blue rays by the minute particles floating in the atmosphere. Now if from the white light of the sun the blue rays are thus selected, those which are transmitted will be yellow, orange and red. Where the distance is short

the transmitted light will appear yellowish. But as the sun sinks towards the horizon the atmospheric distance increases, and consequently the number of the scattering particles. They weaken in succession the violet, the indigo, the blue, and even disturb the proportions of green. The transmitted light under such circumstances must pass from yellow through orange to red, and thus, while we at noon are admiring the deep blue of the sky, the same rays, robbed of their blue, are elsewhere lighting up the evening sky with all the glories of sunset.

Another remarkable triumph of the last half-century has been the discovery of photography. At the commencement of the century Wedgwood and Davy observed the effect produced by throwing the images of objects on paper or leather prepared with nitrate of silver, but no means were known by which such images could be fixed. This was first effected by Niepce, but his processes were open to objections, which prevented them from coming into general use, and it was not till 1839 that Daguerre invented the process which was justly named after him. Very soon a further improvement was effected by our countryman Talbot. He not only fixed his "Talbotypes" on paper—in itself a great convenience—but, by obtaining a negative, rendered it possible to take off any number of positive, or natural, copies from one original picture. This process is the foundation of all the methods now in use; perhaps the greatest improvements having been the use of glass plates, first proposed by Sir John Herschel; of collodion, suggested by Le Grey, and practically used by Archer; and, more lately, of gelatine, the foundation of the sensitive film now growing into general use in the ordinary dry-plate process. Not only have a great variety of other beautiful processes been invented, but the delicacy of the sensitive film has been immensely increased, with the advantage, among others, of diminishing greatly the time necessary for obtaining a picture so that even an express train going at full speed can now be taken. Indeed, with full sunlight $\frac{1}{600}$ of a second is enough, and in photographing the sun itself $\frac{1}{60000}$ of a second is sufficient.

We owe to Wheatstone the conception that the idea of solidity is derived from the combination of two pictures of the same object in slightly different perspective. This he proved in 1833 by drawing two outlines of some geometrical figure or other simple object, as they would appear to either eye respectively, and then placing them so that they might be seen, one by each eye. The "stereoscope," thus produced, has been greatly popularized by photography.

For 2,000 years the art of lighting had made little if any progress. Until the close of the last century, for instance, our lighthouses contained mere fires of wood or coal, though the

construction had vastly improved. The Eddystone lighthouse, for instance, was built by Smeaton in 1759; but for forty years its light consisted in a row of tallow candles stuck in a hoop. The Argand lamp was the first great improvement, followed by gas, and in 1863 by the electric light.

Just as light was long supposed to be due to the emission of material particles, so heat was regarded as a material, though ethereal, substance, which was added to bodies when their temperature was raised.

Davy's celebrated experiment of melting two pieces of ice by rubbing them against one another in the exhausted receiver of an air-pump had convinced him that the cause of heat was the motion of the invisible particles of bodies, as had been long before suggested by Newton, Boyle and Hooke. Rumford and Young also advocated the same view. Nevertheless, the general opinion, even until the middle of the present century, was that heat was due to the presence of a subtle fluid known as "caloric," a theory which is now entirely abandoned.

Melloni, by the use of the electric pile, vastly increased our knowledge of the phenomena of radiant heat. His researches were confined to the solid and liquid forms of matter. Tyndall studied the gases in this respect, showing that differences greater than those established by Melloni existed between gases and vapors, both as regards the absorption and radiation of heat. He proved, moreover, that the aqueous vapor of our atmosphere, by checking terrestrial radiation, augments the earth's temperature, and he considers that the existence of tropical vegetation—the remains of which now constitute our coal-beds—may have been due to the heat retained by the vapors which at that period were diffused in the earth's atmosphere. Indeed, but for the vapor in our atmosphere, a single night would suffice to destroy the whole vegetation of the temperate regions.

Inspired by a contemplation of Graham Bell's ingenious experiments with intermittent beams on solid bodies, Tyndall took a new and original departure; and regarding the sounds as due to changes of temperature he concluded that the same method would prove applicable to gases. He thus found himself in possession of a new and independent method of procedure. It need perhaps be hardly added that, when submitted to this new test, his former conclusions on the interaction of heat and gaseous matter stood their ground.

The determination of the mechanical equivalent of heat is mainly due to the researches of Mayer and Joule. Mayer, in 1842, pointed out the mechanical equivalent of heat as a fundamental datum to be determined by experiment. Taking the heat produced by the condensation of air as the equivalent of

the work done in compressing the air, he obtained a numerical value of the mechanical equivalent of heat. There was, however, in these experiments, one weak point. The matter operated on did not go through a cycle of changes. He assumed that the production of heat was the only effect of the work done in compressing the air. Joule had the merit of being the first to meet this possible source of error. He ascertained that a weight of 1 lb. would have to fall 772 feet in order to raise the temperature of 1 lb. of water by 1° Fahr. Hirn subsequently attacked the problem from the other side, and showed that if all the heat passing through a steam-engine was turned into work, for every degree Fahr. added to the temperature of a pound of water, enough work could be done to raise a weight of 1 lb. to a height of 772 feet. The general result is that, though we cannot create energy we may help ourselves to any extent from the great storehouse of nature. Wind and water, the coal-bed and the forest, afford man an inexhaustible supply of available energy.

It used to be considered that there was an absolute break between the different states of matter. The continuity of the gaseous, liquid and solid conditions was first demonstrated by Andrews in 1862.

Oxygen and nitrogen have been liquefied independently and at the same time by Cailletet and Raoul Pictet. Cailletet also succeeded in liquefying air, and soon afterwards hydrogen was liquefied by Pictet under a pressure of 650 atmospheres, and a cold of 170° Cent. below zero. It even became partly solidified, and he assures us that it fell on the floor with "the shrill noise of metallic hail." Thus then it was shown experimentally that there are no such things as absolutely permanent gases.

The kinetic theory of gases, now generally accepted, refers the elasticity of gases to a motion of translation of their molecules, and we are assured that in the case of hydrogen at a temperature of 60° Fahr. they move at an average rate of 6,225 feet in a second; while as regards their size, Loschmidt, who had since been confirmed by Stoney and Sir W. Thomson, calculates that each is at most $\frac{1}{50000000}$ of an inch in diameter.

We cannot, it would seem at present, hope for any increase of our knowledge of atoms by any improvement in the microscope. With our present instruments we can perceive lines ruled on glass $\frac{1}{90000}$th of an inch apart. But, owing to the properties of light itself, the fringes due to interference begin to produce confusion at distances of $\frac{1}{74000}$, and in the brightest part of the spectrum at little more than $\frac{1}{90000}$th they would make the obscurity more or less complete. If indeed we could use the blue rays by themselves, their waves being much shorter,

the limit of possible visibility might be extended to $\frac{1}{120000}$; and as Helmholtz has suggested, this perhaps accounts for Stinde having actually been able to obtain a photographic image of lines only $\frac{1}{100000}$th of an inch apart. It would seem then that, owing to the physical characters of light, we can, as Sorby has pointed out, scarcely hope for any great improvement so far as the mere visibility of structure is concerned, though in other respects no doubt much may be hoped for. At the same time, Dallinger and Royston Pigott have shown that, so far as the mere presence of simple objects is concerned, bodies of even smaller dimensions can be perceived.

Sorby is of opinion that in a length of $\frac{1}{80000}$th of an inch there would probably be from 500 to 2,000 molecules—500, for instance, in albumen and 2,000 in water. Even, then, if we could construct microscopes far more powerful than any we now possess, they would not enable us to obtain by direct vision any idea of the ultimate molecules of matter. Sorby calculates that the smallest sphere of organic matter which could be clearly defined with our most powerful microscopes would contain many millions of molecules of albumen and water, and it follows that there may be an almost infinite number of structural characters in organic tissues, which we can at present foresee no mode of examining.

The Science of Meteorology has made great progress; the weather, which was formerly treated as a local phenomenon, being now shown to form part of a vast system of mutually dependent cyclonic and anti-cyclonic movements. The storm-signals issued at our ports are very valuable to sailors, while the small weather-maps, for which we are mainly indebted to Francis Galton, and the forecasts, which anyone can obtain on application either personally or by telegraph at the Meteorological Office, are also of increasing utility.

Electricity in the year 1831 may be considered to have just been ripe for its adaptation to practical purposes; it was but a few years previously, in 1819, that Oersted had discovered the deflective action of the current on the magnetic needle, that Ampère had laid the foundation of electro-dynamics, that Schweizer had devised the electric coil or multiplier, and that Sturgeon had constructed the first electro-magnet. It was in 1831 that Faraday, the prince of pure experimentalists, announced his discoveries of voltaic induction and magneto-electricity, which, with the other three discoveries, constitute the principles of nearly all the telegraph instruments now in use; and in 1834 our knowledge of the nature of the electric current had been much advanced by the interesting experiment of Sir Charles Wheatstone, proving the velocity of the current in a metallic conductor to approach that of the wave of light.

Practical applications of these discoveries were not long in coming to the fore, and the first telegraph line on the Great Western Railway from Paddington to West Drayton was set up in 1838. In America Morse is said to have commenced to develop his recording instrument between the years 1832 and 1837, while Steinheil, in Germany, during the same period was engaged upon his somewhat super-refined ink-recorder, using for the first time the earth for completing the return circuit; whereas in this country Cooke and Wheastone, by adopting the more simple device of the double-needle instrument, were the first to make the electric telegraph a practical institution. Contemporaneously with, or immediately succeeding these pioneers, we find in this country Alexander Bain, Breguet in France, Schilling in Russia, and Werner Siemens in Germany, the latter having first, in 1847, among others, made use of gutta-percha as an insulating medium for electric conductors, and thus cleared the way for subterranean and submarine telegraphy.

Four years later, in 1851, submarine telegraphy became an accomplished fact through the successful establishment of telegraphic communication between Dover and Calais. Submarine lines followed in rapid succession, crossing the English Channel and the German Ocean, threading their way through the Mediterranean, Black and Red Seas, until in 1866, after two abortive attempts, telegraphic communication was successfully established between the Old and New Worlds, beneath the Atlantic Ocean.

In connection with this great enterprise and with many investigations and suggestions of a highly scientific and important character, the name of Sir William Thomson will ever be remembered. The ingenuity displayed in perfecting the means of transmitting intelligence through metallic conductors, with the utmost despatch and certainty as regards the record obtained, between two points hundreds and even thousands of miles apart, is truly surprising. The instruments devised by Morse, Siemens, and Hughes have also proved most useful.

Duplex and quadruplex telegraphy, one of the most striking achievements of modern telegraphy, the result of the labors of several inventors, should not be passed over in silence. It not only serves for the simultaneous communication of telegraphic intelligence in both directions, but renders it possible for four instruments to be worked irrespectively of one another, through one and the same wire connecting two distant places.

Another more recent and perhaps still more wonderful achievement in modern telegraphy is the invention of the telephone and microphone, by means of which the human voice is transmitted through the electric conductor, by mechanism that imposes through its extreme simplicity. In this connection the

names of Reiss, Graham Bell, Edison and Hughes are those chiefly deserving to be recorded.

Whilst electricity has thus furnished us with the means of flashing our thoughts by record or by voice from place to place, its use is now gradually extending for the achievement of such quantitative effects as the production of light, the transmission of mechanical power, and the precipitation of metals. The principle involved in the magneto-electric and dynamo-electric machines, by which these effects are accomplished, may be traced to Faraday's discovery in 1831 of the induced current, but their realization to the labors of Holmes, Siemens, Pacinotti, Gramme, and others. In the electric light, gas-lighting has found a formidable competitor, which appears destined to take its place in public illumination, and in lighting large halls, works, &c., for which purposes it combines brilliancy and freedom from obnoxious products of combustion, with comparative cheapness. The electric light seems also to threaten, when subdivided in the manner recently devised by Edison, Swan, and others, to make inroads into our dwelling-houses.

By the electric transmission of power, we may hope some day to utilize at a distance such natural sources of energy as the Falls of Niagara, and to work our cranes, lifts, and machinery of every description by means of sources of power arranged at convenient centres. To these applications the brothers Siemens have more recently added the propulsion of trains by currents passing through the rails, the fusion in considerable quantities of highly refractory substances, and the use of electric centres of light in horticulture as proposed by Werner and William Siemens. By an essential improvement by Faure of the Planté Secondary Battery, the problem of storing electrical energy appears to have received a practical solution, the real importance of which is clearly proved by Sir W. Thomson's recent investigation of the subject.

It would be difficult to assign the limits to which this development of electrical energy may not be rendered serviceable for the purposes of man. * * *

Art. XLVII.—*The Stereoscope, and Vision by Optic Divergence;* by W. LeConte Stevens.

During the last twelve years, Professor Joseph LeConte has published in this Journal a series of articles on Binocular Vision, in one of which he refers to a gentleman with normal eyes "who could combine ordinary stereoscopic pictures with the naked eyes beyond the plane of the pictures, even when the distance between the identical points was greater than the distance between the centers of his pupils." He adds, "It would be curious to inquire, at what *distance* and of what *size*, according to the laws of vision, the stereoscopic image ought to seem in this case."*

While conversing with this gentleman,† about three years ago, it was discovered that I possessed the same power; and since that time no stereograph has been found on which identical points were too far apart to secure binocular fusion with the naked eyes. Not until last spring, however, did I begin any careful investigation of these phenomena. Professor LeConte has investigated the phenomena of ocular convergence very fully, and has developed a system of diagrammatic representation far more consistent than any previously published. I have tested all the experiments on this subject that he has described; and my results have been either identical with his, or as closely approximate as could be reasonably expected. To avoid repetition of what has been already sufficiently established I shall assume that the reader is familiar with the contents of Professor LeConte's papers.‡ It will be found convenient to study optic divergence especially in connection with the stereoscope.

In normal binocular vision the two eyes may be regarded as human cameras occupying slightly different positions, from which are obtained simultaneous views of the point upon which the visual axes are converged. The apparent distance of this point is mainly determined by the intersection of these axes, if the optic angle is large enough to be readily appreciable. In reading ordinary print with comfort the optic angle is rarely less than 12°.

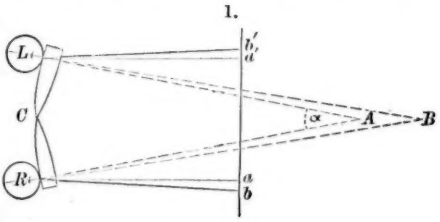
The method of preparing photographs for the stereoscope is too familiar to describe. It is usually assumed that, when these are viewed through the instrument, the lenticular prisms are so adjusted that rays are deviated into the observer's eyes from corresponding points of the stereograph, as if coming from single objects in front; so that he may easily imagine his own

* III, ix, 162–163, March, 1875. † Mr. James Wood Davidson, of New York.

‡ This Journal, II, vol. xlvii, pp. 68 and 153; III, vol. i, p. 33; vol. ii, pp. 1, 315, and 417; vol. ix, p. 159.

eyes to replace the photographer's cameras, and the convergence of his visual axes to replace that of axes from some point in the landscape upon which these cameras have been directed. In fig. 1 let aa' be the foreground interval and bb' that for the background on the stereograph; then the foreground appears at A and the background at B.

1.



To determine the apparent distance of A, let i stand for the observer's interocular distance, RL; α for the optic angle, RAL, and D for the apparent distance required. Then, if a and a' be symmetrical,

$$D=\tfrac{1}{2}i\ \cot\tfrac{1}{2}\alpha.$$

From this equation it is seen that if α be reduced to zero by making the axes parallel, D becomes infinite and there is no intersection. If α be made negative by causing the axes to pass from convergence through parallelism into divergence, D becomes negative and the intersection is behind the observer's head. In either of these cases a physiological impossibility is implied, if we accept the theory that the apparent distance of the combined external image is determined by the intersection of the observer's visual axes. If, therefore, distinct binocular vision is attainable with the axes either parallel or divergent, and any judgment of distance is possible, however faulty it may be, this fact is sufficient to prove that the theory is imperfect, and other elements must be sought for the determination of the judgment of distance in vision through the stereoscope.

In normal binocular vision axial convergence is the most important one of several elements which together determine the apparent distance of the point of sight, provided the real distance of this be near the lower limit of distinct vision. In such cases the formula just deduced is applicable with little or no modification. If i stand for the distance between two photographer's cameras directed to the same point in a landscape, the formula is also applicable to them, provided there be no lack of uniformity in the media through which the rays pass. In normal vision, moreover, both the focal and axial adjustments of the eyes are consensually adapted to the distance of the object regarded, and the deliverances of the muscular sense from the ciliary and rectus muscles conduce to the same judgment of distance. This judgment is the product of the past experience of the individual, and its accuracy must depend largely upon his acquired skill in interpreting muscular sensations, compar-

ing external relations, and remembering the results of such comparisons. If by any means the axial adjustment can be made to differ considerably from that which usually accompanies a given focal adjustment, binocular vision is to that extent abnormal, and the resulting judgment of distance is correspondingly vitiated. It will be shown that vision through the stereoscope is in nearly all cases abnormal, and that optic divergence is not uncommon among those who use this instrument, especially among young persons whose interocular distance is small, whose eyes are normal, and whose power of accommodation, both focal and axial, is hence large

If an observer, who possesses but a single eye, looks out upon a landscape, the relative distance of the different objects viewed may be roughly estimated in terms of some standard arbitrarily chosen, so long as they are not precisely aligned with his eye. The judgment is less accurate as the angular separation of the objects becomes less, and as there are fewer of them at moderate distances with which to compare the rest. Always, and often unconsciously, he employs one or more of the following elements in judging the distance and form of each object regarded.

I. Near objects subtend larger visual angles than remote objects of equal size.

II. Near objects are seen more distinctly than those that are remote. The illusion of distance may hence be produced by decreasing the brightness of the object viewed, by changing the nature of the medium, or by increasing the contrast between light and shade.

III. Near objects, that are almost aligned with those which are remote, partly cover them. Covering objects are judged nearer than those covered.

IV. Familiarity with the dimensions of known objects when near enables us to compare them when remote and thereby judge their relative distance.

V. By moving from one standpoint to another and comparing the new view with what is retained in memory of the previous one, parallax of motion thus contributes to the formation of a judgment of both distance and form.

The mere synopsis of these elements is all that is necessary; separately they are familiar enough, and to illustrate them would be easy. Every one of them may be employed in the use of each eye, either separately or in conjunction with its companion. For distances of more than 240^{m} the binocular observer has no advantage except that two eyes receive more light than one, and the combined external image hence appears brighter and more distinct. All of them except the last may be imitated in pictures, and some of them, notably the second, may be heightened by the magnifying effect of lenses. In study-

ing binocular vision they must be eliminated as far as possible; and all except the first may be nearly eliminated by using only skeleton pictures. In ordinary stereographs their combined effect is usually greater than that due to binocular perspective.

If for convenience we apply the term physical perspective to the combined effect of the elements enumerated, then that of focal and of axial adjustment may be called physiological perspective. The latter might be regarded as mathematical if the theory set forth at the beginning of this paper were strictly applicable in all cases. It is well known that focal adjustment does not vary sensibly for distances of more than 6^m, and that its effect is greatest just beyond the near limit of distinct vision, which is also about the average distance at which a stereoscope card is held when regarded. It is also well known that in normal binocular vision, the convergence of axes does not vary sensibly for distances of more than 240^m. In abnormal vision convergence may be diminished until the limit of parallelism is passed; and the judgment of distance continues to be affected by the relaxation of the interior rectus muscles, or contraction of the exterior rectus, or by both, while the focal adjustment is still adapted to the distance of the object in front held as near as convenient. The judgment of distance which results from the conflict of elements produced by this unusual coördination of muscular actions is necessarily by no means mathematical in accuracy.

While the possibility of securing divergence of axes for normal eyes has been long known, no analysis of the visual phenomena in binocular vision by this method has appeared in print, so far as I am aware. Professor LeConte's diagrams show how to determine the apparent direction of the object viewed, but he says,* "there is no point of sight." There is certainly none determined by intersection of visual axes. In reference to images perceived by abnormal vision, Helmholtz says,† "we judge them according to their nearest resemblance; and in forming this judgment we more easily neglect the parts of the sensation which are imperfect than those which are perfectly apprehended." In combining stereoscope pictures by axial divergence, either with or without the instrument, I secure vision so clear that no defect is appreciable at any point however carefully scrutinized; it does not seem necessary then to assume that any parts of the sensation are neglected. The case was very slightly otherwise during my first experiments in divergence. He makes also the following observation, that I translate from the French edition, which is the latest, of his work on Physiological Optics:‡ "When we compare a stereoscopic

* This Journal, III, vol. ix, p. 163.
† Popular Lectures on Scientific Subjects, 1st series, p. 307.
‡ Optic Physiologique, p. 828, edition 1867.

image, observed by divergence of the visual lines, with very remote real objects visible above the stereoscope, such as a remote chain of mountains, the stereoscopic image appears to us much more remote than real objects the most distant." The apparent anomaly of binocular vision without convergence of axes he refers, in this connection, to our "comparing the sensation produced with that which resembles it the most, and which is not distinguishable from it but by feebler convergence, that is, with what very remote objects give us." So far as axial divergence alone is effective, I am unable to sustain Helmholtz's observation; nor is it sustained by those whom I have tested, every one of them giving results closely accordant with my own, care having been taken to prevent any previous knowledge of my object in questioning them. All that is essential is to secure axial divergence and compare the binocular effect with the monocular effect of the same picture, if the original landscape be not present. Before me is a stereograph representing Alpine scenery, which I combine binocularly, with from 2° 17′ to 2° 40′ of divergence, as foreground and background are successively regarded. On closing the left eye, the apparent distance of a remote mountain is not perceptibly diminished; indeed on account of the decreased brightness of the monocular image, the mountain seems slightly farther. To eliminate physical perspective as much as possible, this being always strong in pictures of landscapes, a stereograph is now taken, representing a white marble statue against a dark background; the stereographic interval can be varied at will, the card having been cut in two. Placing this in the stereoscope, the two pictures are drawn apart until 5° of axial divergence is attained, the experiment being made at a window from which an extensive landscape can be seen for the purpose of comparison. By no effort of imagination can I estimate the apparent distance of the statue to be more than 10^{m}. A stereograph representing a skeleton cone is now substituted, but with the same result.

It may be safe to say therefore that if Helmholtz was examining, by axial divergence in the stereoscope, a picture of the same landscape that lay actually before him, the mountains in the picture appeared farther off than those with which they were at once compared by normal vision with both eyes, all the elements of physical perspective being the same in both cases. This is probably what he meant. But his remark is not necessarily or generally applicable when stereograph and landscape are unrelated. Mere divergence of axes is not enough to reverse physical perspective, but may modify it to some extent and introduce special illusions.

[To be continued.]

ART. XLVIII.—*Note on the Electrical Resistance and the Coefficient of Expansion of Incandescent Platinum;* by E. L. NICHOLS, PH.D. (Göttingen).

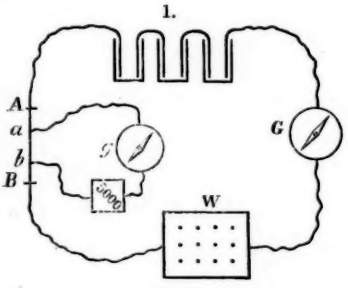
[Read at the Cincinnati Meeting of the American Association for the Advancement of Science, August, 1881.]

I. IN the measurement of temperatures above the red heat, the platinum pyrometer, in one form or another, is as important as the mercury thermometer, at ordinary temperatures. The researches already completed, on the electric resistance and the coefficient of expansion of platinum, and on the specific heat of that metal, only serve, however, to remind us of the much that remains to be done before we may hope to attain to even a fair degree of accuracy in the measurement of temperatures above 500°.

The present writer in order to compare the existing formulæ for the temperature of platinum from its electric-resistance, with those by means of which the temperature is calculated from the coefficient of expansion, and thus to gain a clearer idea of the relative usefulness of the two methods, has determined the resistance and the corresponding length of a platinum wire at various temperatures between 0° and the melting point of that metal.

II. Upon a platinum wire $0{\cdot}4^{mm}$ in diameter and 100^{mm} long, at points 55^{mm} apart and equally distant from the middle of the wire, two very fine platinum wires were welded. They served to mark the ends of the portion of the wire to be measured, and to make electrical connection with a shunt containing a sensitive galvanometer. The wire was heated by the current from a battery of forty Bunsen's cells. Its resistance was determined by the following method.

The wire (AB) (figure 1) together with a tangent galvanometer (G) and a resistance box (W) was in direct circuit with the Bunsen's battery. A very small portion of the current was shunted around *ab*, the portion of the wire to be tested, and carried through a sensitive sine galvanometer (*g*) and through a resistance coil (*w*) of 5000 ohms.



Now with the above arrangement of apparatus, if *w* is very much larger than *r*, the resistance of the wire *ab*, so that the

current through *ab* is not sensibly less than that through the main circuit, we shall have,

$$E=\frac{C}{r}=\frac{C'}{r'},$$

where C and C′ are the currents through *ab* and through the shunt, and r' is the resistance of the shunt.

But

$$C'=\sin U k'$$
$$C=\tan V k$$

where U is the deflection of the sine galvanometer and k' the constant of the instrument, and where V is the deflection of the tangent galvanometer and k the constant of the latter instrument.

Then

$$r=\frac{\tan V}{\sin U}\cdot\frac{k}{k'}=\frac{\tan V}{\sin U}\cdot K$$

where

$$K=\frac{k}{k'}r'.$$

The length of the wire *ab* was measured by bringing the two microscopes of a comparator into such position that the terminal (*a*) was in focus in the field of one of the microscopes and (*b*) in the field of the other. Since these points were quite as near the middle as the end of the wire, every change of temperature caused a movement of both (*a*) and (*b*); and it was by taking the differences of these that the true change in the length of *ab* was determined. As the microscopes were provided with excellent micrometer scales and screws, a fair degree of accuracy was obtained by this method. Readings of the length of the wire at 20° agreed with a series taken upon a dividing engine of known accuracy, to within ·002^{mm}. The distance *ab* at 20° was found to be 53·5576^{mm}.

The resistance of the cold wire was found—in terms of U, V and K—by placing the wire in a napthaline bath, and obtaining values of U and V with various amounts of currents. From these readings a curve was drawn with $\frac{\tan V}{\sin U}$ as abscissæ and $\tan^2 V$ as ordinates, $\tan^2 V$ being taken as an expression for the heating effect of the current. The point of this curve corresponding to $\tan^2 V=0$ was taken as the proper value of $\frac{\tan V}{\sin U}$ for the cold wire.

In measuring the resistance of the hot wire, the galvanometers were read simultaneously before and after each determination of the length.

The following table gives the results of the measurements, for temperatures ranging between 0° and a point not far below the melting point of platinum. Both resistance and length of wire at 0° are taken equal to unity.

TABLE I.

Resistance.	Length.	Resistance.	Length.
1·0000	1·00000	3·7090	1·01229
1·0410	1·00002	3·7427	1·01223
1·5071	1·00125	3·7813	1·01285
1·9000	1·00289	3·8750	1·01349
2·1212	1·00380	3·8904	1·01371
2·2934	1·00456	3·9305	1·01378
2·3035	1·00489	4·0303	1·01450
2·7821	1·00732	4·0631	1·01469
2·8633	1·00763	4·0655	1·01495
2·9696	1·00809	4·0747	1·01499
3·3533	1·01022	4·0841	1·01514
3·3741	1·01003	4·1248	1·01540
3·4151	1·01042	4·2005	1·01567
3·6449	1·01160	4·2447	1·01632

III. Dr. Siemens has published three formulæ for the variation of the resistance of a platinum wire with the temperature. The temperatures were calculated in one case (formula *a*) from the heating effect of a copper ball, the specific heat of copper being regarded as a constant, while the other two formulæ were derived from measurements with the air-thermometer.

These formulæ are:

$$(a)\quad r = \cdot 039369\ T^{\frac{1}{2}} + \cdot 00216407\ T - \cdot 24127$$

$$(b)\quad r = \cdot 0021448\ T^{\frac{1}{2}} + \cdot 0024187\ T + \cdot 30425$$

$$(c)\quad r = \cdot 092183\ T^{\frac{1}{2}} + \cdot 00007781\ T + \cdot 50196$$

where T is the absolute temperature and r the resistance of the wire. The following formula by Benoit is also sometimes used for the determination of high temperatures.

$$(d)\quad r = 1 + \cdot 002445\ t + \cdot 000000572\ t^2.$$

In this expression t denotes the temperature in degrees centigrade.

When, as is frequently the case, it is more convenient to measure the length of a wire than its resistance, we may employ Matthiesen's formula,

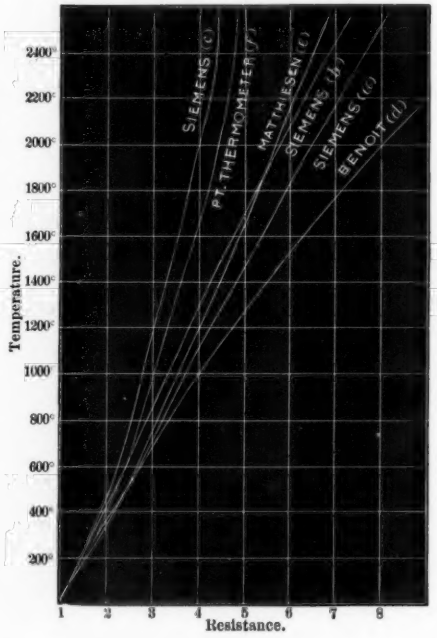
$$(e)\quad l = l_0(1 + \cdot 00000851\ t + \cdot 0000000035\ t^2)$$

or we may use the uncorrected scale of the platinum thermometer. The latter scale is expressed by the formula

$$(f)\quad l = l_0\,(1 + \cdot 00000886\,t).$$

These being almost the only data we possess for the calculation of the temperature of a hot wire, the question of their accuracy is of some importance. The formulæ may be best compared by plotting side by side the curves which represent them (fig. 2).

2.



In fig. 2, resistance is substituted for length in curves (*e*) and (*f*), using for that purpose the measurements given in Table I. The following table affords a further comparison of the six formulæ.

In the columns (*a*) to (*f*) are given the temperatures, calculated by the several formulæ, at which the resistance of the wire, compared with its resistance at 0°, is given in the column marked "*r*."

TABLE II.

Length.	r	Siemens.			Benoit.	Matth.	Pt. thermom.
		a	b	c	d	e	f
1·0000	1·000	0°	0°	0°	0°	0°	0°
1·0032	2·000	325°	402°	420°	378°	342°	375°
1·0082	3·000	692	812	1108	708	726	917
1·0146	4·000	1086	1244	1950	1000	1170	1623
1·0280	5·000	1464	1682	3170	1272	1638	3100
- --	6·000	1828	2072	----	1512	2158	----
----	7·000	2170	2387	----	1766	2800	----
----	8·000	2470	2692	----	1978	----	----
----					----		

A glance at the curves and at this table suffices to show how ill-deserved is the confidence generally felt in these formulæ. The discrepancies involve differences of hundreds of degrees.

IV. The methods employed by Dr. Siemens in the measurements represented by curves *b* and *c* were identical; but the platinum used contained slight impurities. To these impurities the disparity was due. Dr. Siemens found that such foreign substances as usually occur in commercial platinum affected both the resistance of the cold metal and the law of the change of resistance with the temperature.

Benoit's formula (*d*) depends for its accuracy upon the determination of the boiling points of mercury, sulphur, cadmium and zinc; for which temperatures he adopted the values given by Deville and Troost.* M. Ed. Becquerel opposed those values at the time of their publication, and later researches have confirmed him, at least so far as cadmium and zinc are concerned, in thinking them to be entirely too high.

In the following table the results obtained by Deville and Troost are compared with the more probable values given by other physicists.

TABLE III.

Metals.	Boiling points. Dev. and T.	Boiling points. Other values.		
Hg.	360°	350°	Regnault.	
S.	440	448	Bennett,	This Journal, 1878.
		446	Carnelly and	Quart. Jour. Chem. Soc.,
Cd.	860	772	Williams,	1876–78.
Zn.	1040	884	Becquerel,	Comptes Rendus, 57.

The substitution of these values in Benoit's formula, places it more at variance than before with the measurements of Matthiesen and Siemens; a variation probably due to the

* Deville and Troost Annales de Chimie, III, vol. lviii.

difference of behavior noticed by the latter physicist in the case of different specimens of platinum.

The brief discussion of the above mentioned results suffices we think to show, that:

1st. The formulæ in question are based for the most part upon unwarrantable suppositions, such as the constancy of the specific heat of copper and of platinum; the constancy of the coefficient of expansion of the latter metal, and upon the accuracy of certain very doubtful values for the boiling points of zinc, cadmium, etc.

2d. That, aside from the inaccuracy of those data, the varying resistance of different specimens of platinum renders any formula for the calculation of temperature of that metal from its electric resistance applicable only to the identical wire for which the law of change of resistance with the temperature has been determined.

3d. That from the data at command we are not in position to calculate the temperature of an incandescent platinum wire from its change of resistance, nor from its length, nor indeed in any other manner, further than to express the temperature in terms of the length or the resistance of the wire.

4th. That, owing to the great variations shown by different specimens of platinum as regards its resistance, the determination of the expansion of the wire is to be preferred, whenever practicable, to the measurement of its conductivity.

Art. XLIX.—*On Local Subsidence produced by an Ice-sheet;* by W. J. McGee.*

The influence of a polar ice-cap on the earth's center of gravity has been computed by Croll and others on the supposition of an inflexible crust. But geological investigation has demonstrated that the terrestrial crust is flexible, and hence subject to local deformation. Now the problem requiring the influence of an ice-cap on the earth's center of gravity, on the supposition of a flexible crust, is so complex as to be incapable of solution in the present state of knowledge; but the local deformation may be considered.

The subsidence of areas of deposition is a well-known phenomenon, attested by unequivocal evidence in many parts of the globe. The single instance, cited by Dutton ("Geology of the High Plateaus of Utah," p. 13), of the subsidence of the terrestrial crust in Utah during the Cretaceous-Eocene time to the extent of 6,000 to 15,000 feet, may be here referred to. From

* Supplementary note to p. 267 (line 33) of the last number of this Journal.

this and other instances it appears that a mass of sediment produces a deformation equal to its own thickness. Now since the specific gravity of ice to average rock is something over 1 : 3, it follows that an ice-sheet three miles in thickness ought to depress the subjacent strata about a mile.

But *time* is an important element in the motion of all imperfectly fluid bodies. The approximate numerical equivalence between cause and effect in cases of subsidence with deposition indicates that if sufficient time be given the rigidity of the terrestrial crust is practically *nil;* though it is probable that the function is variable and represented by an infinite series, no terms of which are known. The time of continuance of quaternary ice to that of the deposition of the Cretaceous and Eocene sediments in Utah is as some unknown ratio, probably between 1 : 100 and 1 : 10,000;—say 1 : 1,000. If, however, the deformation during various times is represented by an infinite series, the ratio between quaternary and Cretaceous-Eocene subsidence is much higher—say 1 : 10. The subsidence produced by an ice-sheet three miles in thickness ought accordingly to be only 500 or 600 feet. It will be understood that while it is certain that subsidence would occur, very little value can be attached to this estimate of its amount.

The hydrostatical principles in accordance with which deformation beneath a thick ice-sheet must occur, equally demand that the crust should return to its original form after the melting of the ice; and it is manifest that as much time would be required to produce this secondary as the primary deformation. Assuming then that the periods of advance and retreat, or of growth and decay of the ice are of like duration, it follows that *the earth's surface must continue below the normal level at any latitude, after the withdrawal of the ice, for as long a period as that during which the ice remained stationary at that latitude.*

Should the application of the principles sought to be elucidated in the paper on "Maximum Synchronous Glaciation" to any single continental area ever be attempted, the foregoing considerations will afford a means of testing their accuracy; for late-quaternary depression, being accompanied by submergence in all low-lying areas, has left unmistakable traces, not only of its occurrence but of its extent, in many localities.

Farley, Iowa, Sept. 15, 1881.

ART. L.—*Note on the Laramie Group of Southern New Mexico;* by JOHN J. STEVENSON, Professor of Geology in the University of New York.

IN a former paper* the writer gave some notes respecting the Laramie of Southern New Mexico, as shown in the vicinity of Galisteo creek. Some additional facts respecting the same, obtained during the present summer more than one hundred miles south from Galisteo creek, may be of interest.

The Laramie group is practically continuous on the east side of the Rio Grande Valley, southward from Galisteo creek, to certainly five or six miles beyond San Pedro, or one hundred and fifty miles south from Santa Fe. Coal beds have been opened near Galisteo creek, in the vicinity of the Tuerto mountains, near the Sandia mountains, and at several other localities as far south as San Pedro. The outcrop on the east side of the Rio Grande Valley has been carefully traced and mapped by Mr. J. M. Robinson, for the Atchison, Topeka and Santa Fe railroad company. The absolute continuity of the field is interrupted only by a few narrow cañons and the bluffs marking the western edge of the area can be followed as easily as those marking the eastern edge of the Trinidad coal field in northern New Mexico.

The San Pedro locality is nearly nine miles east from the Rio Grande, and is about twenty-three miles south-southeast from the city of Socorro, whence it can be reached conveniently by a wagon road passing through the villages of San Antonio and San Pedro; but before long it will be more convenient of access, as the railroad company contemplate building a branch road to the coal.

In this southern part of the field one observes the same features as on the Galisteo. Instead of the yellow or buff sandstones which predominate in the Trinidad and Cañon City coal fields, shales prevail, and for the most part the sandstones are soft and often argillaceous. Thin beds of hard, fine-grained sandstone are shown, with distinct jointing and breaking into angular fragments, which retain their sharpness even after long exposure to the weather. When seen from a little distance these thinner beds resemble sheets of igneous rock. As on the Galisteo, beds of iron ore with concretionary structure are numerous, as also are beds of ferruginous clay with cone-in-cone structure. These ferruginous beds are not confined to the lower part of the group. The shales are drab to black and in many of the beds are fissile.

* This Journal, vol. xviii, p. 371.

At the San Pedro locality, four beds of coal were seen within a vertical distance of barely one hundred feet. The lowest bed has the following structure:

Upper division,		
Coal	0′ 8″	
Clay	2′ 6″	
Coal	1′ 4″	
Shale		2′ 3″
Lower division		6′ 9″
Coal	4′ 4″	
Clay	0′ 2″	
Coal	2′ 3″	

The blossom of the next bed at nearly twenty feet higher is somewhat more than five feet thick. The bed contains much coal but it is so broken by partings that perhaps the whole may be unavailable. The third bed is but two or three inches thick and is embedded in dark shale. The highest appears to be little more than two feet thick, the estimate being made from its badly weathered blossom. The dips are southward and vary from seven to fifteen degrees.

The lowest coal bed has been opened by a slope one hundred and fifty feet long, and a large quantity of the coal has been tested on the railroad engines where it worked satisfactorily. Its quality varies in different parts of the bed and the differences in physical characteristics suggest that the relation between fixed carbon and volatile matter may vary in the several benches. The coal from some portions closely resembles semi-anthracite, while that from others cokes readily. This opening is not new, coal having been obtained from it years ago to supply Fort Craig.

These beds belong at not less than two hundred feet above the base of the group.

That this field belongs at the same horizon with the Trinidad coal field has been announced by Mr. Lesquereux, Dr. Hayden and the writer, as proved by the stratigraphy and by the testimony of the fossil plants. In the paper already referred to the writer stated that he had observed on the Galisteo an unexpected intimacy between the Laramie and the Fort Pierre and that he had obtained *Ostrea congesta* from a ferruginous bed high up in the Laramie. This intimacy is much more marked at the San Pedro locality. Stratigraphically and lithologically there is no means of distinguishing the Laramie from the Fort Pierre, aside from the coal beds. Were these absent an observer would hardly hesitate to regard the whole as one group, for there is much less of sandstone here than on the Galisteo. The ferruginous beds with cone-in-cone structure appear to be wholly non-fossiliferous on the Galisteo, but at

the San Pedro locality these beds are fossiliferous, though not to the same extent as the ore-beds. The presence of marine fossils was not ascertained until just before leaving the place, and but a few minutes remained in which to collect. The specimens therefore are such only as could be broken hastily from the weathered surface of the beds, and in most cases suffice for merely generic determination. The list as determined by Prof. R. P. Whitfield is as follows:

Ostrea glabra; Anomia; Corbula, 3 species; *Camptonectes?; Tellina ?*, and a fragment of some gasteropod.

ART. LI.—*Polariscopic Observations of Comet c*, 1881; by ARTHUR W. WRIGHT.

THE path of this comet in the sky did not bring it into positions the most favorable for observation, but while near the perihelion it continued for a short time each evening at a sufficient altitude to escape the influence of twilight, though never far enough above the horizon to be viewed under entirely satisfactory conditions. Although these circumstances prevented the attainment of anything like a complete series of observations, it was found possible to establish the fact of polarization, and even to secure some measurements. Owing to the extreme faintness of the light, these were obtained with some difficulty, and were limited to a small number.

The first successful observation was made on August 16, from 9^h to 10^h P. M., local time. With a double-image prism, placed before the eye-piece of a comet-seeker having an aperture of three inches, and a magnifying power of about eight diameters, the light was easily seen to be polarized in a plane passing through the sun. That there might be no doubt upon this point, two other persons were requested to view the images as they appeared in the instrument. Both found one of them fainter in certain positions of the prism, and in every case correctly designated that one which accorded with polarization in the direction above described, and this without any intimation as to the result to be expected. The light was just sufficient, when the polarimeter was applied, to enable the bands to be seen with great difficulty, but measurements were impossible.

A few evenings later some polarimetric determinations were obtained, the results of which are brought together in the annexed table. The instrument and method employed were the same as described in the account of observations upon comet *b*.* Column I gives the date and local time; in column

* This Journal, vol. xxii, Aug., 1881, p. 142; Copernicus, No. 8, p. 157; The Observatory, No. 53, p. 253.

II each number is the percentage of polarization derived from ten separate measurements; column III gives the mean of these for each evening; in column IV are given the angles of incidence of the solar rays. These are obtained by graphic interpolation from a curve representing the angles calculated from the ephemeris of H. Oppenheim,* for the dates there given.

I.	II.	III.	IV.
Aug. 20, $8^h\ 30^m$ to $9^h\ 30^m$, P. M.	13·4 14·2	13·8	54°·6
Aug. 22, $8^h\ 30^m$ to $9^h\ 15^m$, P. M.	11·0 9·7	10·3	55°·6
Aug. 25, $8^h\ 30^m$ to 9^h, P. M.	10·5 11·6	11·0	55°·2
Aug. 27, $8^h\ 30^m$ to 9^h, P. M.	[16·8]	[16·8]	54°·1

The percentage for August 27 was obtained from two settings of the plates only, and is entitled to less confidence than the others. That the polarization was really increasing, however, was easily recognized by the appearance of the bands, and their relative brightness in the two positions of the glass plates. After this date the condition of the sky was not at any time such as to render further determinations possible. At the hours of the observations the last vestiges of twilight had apparently disappeared; and a careful examination of the neighboring regions of the heavens with the instrument failed to give evidence of its presence, or of any polarization in the very faint light of the sky.

A comparison of the results above given with those obtained in the observations of comet *b*, 1881,† shows that for corresponding angles of incidence the polarization was decidedly less than in the case of the latter comet. There appears also to be a difference in the relation of the percentages to the angles of incidence. Comet *c*, during the period when measurements were possible, changed its position in such a way that the angle first increased and then decreased, the change in each case being very small. It is so little, in fact, that some uncertainty must be felt as to its character, since the data of the published ephemerides lead to considerably different values. That of Oppenheim, however, which was employed in computing the series, as above mentioned, agrees very well with reported observations of position of the comet made during the period covered by the dates in the table. The results found as above indicate that the polarization, for this comet, conforms in general to the law of variation for a gaseous medium, where the curve representing it has the maximum at the incidence of

* Astron. Nachr., No. 2388, p. 190. † Loc. cit.

45°, and changes very rapidly in the region corresponding to the incidences given in the table.

In the case of comet *b*, the largest angle of incidence was nearly 60°, and as this diminished the polarization was seen to diminish likewise; but it happened that at the times of widest incidence the comet was near its perihelion. A maximum occurring with an incident angle as large as 60° would hardly be looked for if the degree of polarization depended upon this angle alone. If the reflecting material were wholly gaseous the greatest polarization should be found at 45° incidence; but though a tendency toward a secondary maximum at this angle may be suspected, the observations are not sufficient to definitely establish its existence. The changes actually observed are with difficulty reconciled with the supposition that the reflection took place from gaseous substance alone. It is not improbable that, as the comet was nearing the sun, and while it remained near the perihelion, some form of volatizable matter may have been eliminated by the increasing temperature, and that the subsequent condensation of this gave rise to the presence of minute liquid or solid particles in the gaseous matter first thrown off. The varying proportions of these two forms of matter might be the cause of notable variations in the total amount of light polarized. It is, of course, not to be overlooked that the substance of the coma, and probably that of the tail, gives out light of itself. The action just described must alter the relation of the emitted to the reflected rays, and this would have its effect upon the degree of polarization.

The earlier observations of comet *b*, made soon after its perihelion passage, show occasional irregularities, and the variations are in some cases decidedly greater than the ordinary errors of observation. The sky at the time appeared very clear, and the atmospheric conditions were probably not the sole cause of the fluctuations. It seems almost certain that at this period of great activity the polarization was subject to considerable variations of an irregular character and comparatively brief duration.

Yale College, October 15, 1881.

ART. LII. — *On the Relative Accuracy of Different Methods of Determining the Solar Parallax*; by WM. HARKNESS.

[The substance of this paper was read before the American Association for the Advancement of Science, at Cincinnati, August, 1881.]

THE object of this paper is to compare the various methods of determining the solar parallax, and to show that the photographic method employed by the United States Transit of Venus Parties in 1874 is among the most accurate known, and should not be neglected in observing the transit of 1882.

The following notation will be employed in algebraic formulæ:

a = mean distance of the earth from the sun.
a_1 = that distance between the earth and the sun which would satisfy Kepler's third law.
a_2 = mean distance of the earth from the moon.
c = a constant such that $c\rho = \rho_1$.
E = the mass of the earth.
e = eccentricity of the moon's orbit.
e_1 = eccentricity of the earth's orbit.
G = observed force of gravity at a point upon the surface of the earth.
k = Gauss's constant for the solar system.
L = constant of the earth's lunar inequality.
l = length of simple pendulum.
M = the mass of the moon.
m = ratio of the mean motions of the sun and moon = 0·07480133.
P = the constant of lunar parallax = 3422″·7.
P_1 = that value of the constant of lunar parallax which would satisfy Kepler's third law.
p = the constant of solar parallax.
Q = the parallactic inequality of the moon.
S = the mass of the sun.
s = geocentric latitude of the moon.
T = length of the sidereal year, expressed in seconds of mean time = 31,558,149^s.
T_1 = length of the sidereal month, expressed in seconds of mean time = 2,360,591^s·8.
t = time.
V = the velocity of light.
α = the constant of aberration.
γ = Delaunay's constant, which is approximately sin ½ (inclination of lunar orbit to plane of ecliptique), and the exact value of which is 0·04488663. See DTL., vol. ii, 802.
θ = the time taken by light to traverse the mean radius of the earth's orbit.
μ = motion of moon's node, relatively to the line of equinoxes, in 365¼ days.
ν = the heliocentric longitude of the earth.

ν' = the geocentric longitude of the moon.
ρ = the equatorial radius of the earth.
ρ_1 = radius of the earth at latitude φ.
φ = geocentric latitude.
Ψ = the luni-solar precession.
Ω = the constant of nutation.

In citing authorities the following abbreviations will be used:

MAc = Memoires de l'Académie Royale des Sciences. Paris.
HAc = Histoire de l'Académie Royale des Sciences. Paris.
CRH = Comptes Rendus Hebdomadaires des séances de l'Académie des Sciences. Paris.
PTr = Philosophical Transactions of the Royal Society of London.
ANn = Astronomische Nachrichten.
MAS = Memoires of the Royal Astronomical Society. London.
MNt = Monthly Notices of the Royal Astronomical Society, London.
OPM = Annales de l'Observatoire Impérial de Paris. Mémoires.
WOb = Astronomical and Meteorological Observations made at the United States Naval Observatory. Washington.
PTL = Théorie du Mouvement de la Lune, par Jean Plana. Turin, 1832. 3 vols. 4to.
DTL = Théorie du Mouvement de la Lune, par Ch. Delaunay. Paris, 1860–1867. 2 vols. 4to.

Every known method of determining the solar parallax belongs to one or other of the following classes, namely:

I. Trigonometrical methods.
II. Gravitational methods.
III. Photo-tachymetrical methods.

We will consider them in their order.

Trigonometrical Methods.

Observations of Mars, when in opposition to the sun, and at its least distance from the earth, constitute one of the oldest trigonometrical methods of determining the solar parallax. There are two ways of making the observations. Either the planet is observed on or near the meridian, at two stations, situated respectively in the northern and southern hemispheres; or it is observed soon after rising, and just before setting, at a single station. The first method will be termed the meridian method; the second, the diurnal method. In the meridian method the observations may be made either with a transit circle, or with a micrometer attached to an equatorial telescope. In the diurnal method they may be made either with an equatorial telescope, or with a heliometer.

The values of the solar parallax resulting from some of the most noteworthy attempts by the meridian method are as follows:

1672. J. D. Cassini (MAc, viii, 114), ... 9″·5
1751. Lacaille (Ephémérides des Mouvements Célestes depuis 1765 jusqu'en 1774. Paris. Introd. p. 1), 10·38
1835. Henderson (MAS, viii, 103), ... 9·028
1856. Gilliss and Gould (U. S. Ast. Ex. to the South. Hemisphere, vol. iii, p. cclxxxviii), ... 8·495
1863. Winnecke (ANn, Bd. lix, s. 264), ... 8·964
1865. E. J. Stone (MAS, vol. xxxiii, p. 97), ... 8·943
1865. A. Hall (WOb, 1863, App. p. lxiv), ... 8·842
1867. Newcomb (WOb, 1865, App. II, p. 22), ... 8·855
1879. Downing (ANn, Bd. xcvi, s. 127), ... 8·960

The following are some of the results from the diurnal method:

1672. J. D. Cassini (MAc, viii, 107), ... 10″·2
1672. Flamstead (PTr, 1672, p. 5118), ... 10.
1719. Bradley and Pound (Gehler's Physikalisches Wörterbuch, viii, 822), ... 10·5
1857. W. C. Bond (Gould, Ast. Jour., v, 53), ... 8·605
1877. Maxwell Hall (MAS, vol. xliv, p. 121), ... 8·789
1879. Gill (MNt, 1879, vol. xxxix, p. 437), ... 8·78

Owing to the comparative nearness of the asteroids, and their small, well defined disks, it has been thought that the solar parallax might be accurately derived from observations made upon them in the manner just described for Mars. So far as I know, the following are the only attempts which have been made in that direction:

1875. Galle, from Flora (ANn, Bd. lxxxv, s. 267), ... 8″·879
1877. Lindsay and Gill, from Juno (Dunecht Observatory Publications, vol. ii, 211), ... 8·765

The same method has also been applied to Mercury and Venus, but there are great difficulties in the way of obtaining satisfactory results from these planets.

Transits of Venus.—Until quite recently, astronomers have believed that transits of Venus furnish by far the most accurate means of determining the solar parallax. Such transits have been observed by three different methods, namely: 1. By noting the times of contact between the limbs of Venus and the sun. 2. By observing the position of Venus upon the sun's disk with a heliometer. 3. By photographing the sun with Venus upon its disk, and subsequently measuring the photographs.

Contact observations.—The following are some of the results for solar parallax obtained by different astronomers from contact observations of the transits of Venus in 1761, 1769 and 1874:

TRANSIT OF 1761.

1763.	Hornsby (PTr, 1763, p. 494),	9″·73
1763.	Short (PTr, 1763, p. 340),	8·56
1765.	Pingré (HAc, 1765, p. 32),	10·10
1767.	Planman (PTr, 1768, p. 127),	8·49

TRANSIT OF 1769.

1770.	Euler (Novi Commentarii Ac. Sc. Petropol., t. xiv),	8″·8
1771.	Hornsby (PTr, 1771, p. 579),	8·78
1771.	Lalande (HAc, 1771, p. 798),	8·62
1771.	Maskelyne,	8·723
1772.	Lexell,	8·63
1772.	Pingré (HAc, 1772, p. 419),	8·80
1772.	Planman,	8·43
1814.	Delambre (Astron. Théorique et Pratique, t. i, p. xliv),	8·552
——.	Du Sejour (Traité Analytique des Mouvements Apparent des Corps Celestes, t. i, pp. 451–491),	8·85
1832.	Ferrer (MAS, v, 286),	8·58
1865.	Powalky (Conn. de Temps 1867 Additions, p. 22),	8·832
1868.	E. J. Stone (MNt, vol. xxviii, p. 264),	8·91

TRANSITS OF 1761 AND 1769.

1835.	Encke (Abhand. der Akad. zu Berlin, 1835, Math. Kl., s. 309),	8·571

TRANSIT OF 1874.

1877.	Airy (The Observatory, 1877, vol. i, p. 149),	8·760
1878.	Tupman (MNt, 1878, vol. xxxviii, p. 455),	8·846

The large differences in the parallaxes obtained by different astronomers from the same observations are due to the circumstance that, as the instants of contact are rendered uncertain by the intervention of various disturbing phenomena, many of the observers record two or three different times, corresponding to as many different phases which they endeavor to describe, and thus the resulting parallaxes are influenced to a certain extent by the interpretation put upon these descriptions. The interior contacts give better results than the exterior ones, but in any case the probable error is large. From sixty-one selected observations of interior contacts of the transit of December, 1874, discussed by Col. Tupman (MNt, 1878, vol. xxxviii, 20 on page 450, and 41 on p. 453), I find the probable error of an observed time of contact to be $\pm 4^{s}\cdot 59$, which corresponds to a probable error of $\pm 0''\cdot 15$ in the distance between the centers of the sun and Venus. Actual errors of from twenty to thirty seconds in the observed times of contacts are by no means uncommon.

Observations with heliometers.—A few heliometers were used in observing the transit of December, 1874, but I am not aware

that anything has yet been published which suffices to show how accurately they will furnish the solar parallax.

Photographic observations.—For observing the last transit of Venus there were used at least two kinds of photoheliographs, constructed upon widely different principles. In what follows I shall consider only the results yielded by apparatus of the kind used by the United States Transit of Venus parties.

As the reductions of the United States transit of Venus observations are not yet quite completed, it is impossible to say exactly what degree of accuracy the photographs will give; but fortunately the same instruments which were used in December, 1874, to observe the transit of Venus at Kerguelen Island, Hobart Town and Peking, were used in May, 1878, to observe the transit of Mercury at Cambridge, Mass., Washington, D. C. and Ann Arbor, Mich.; and as the transit of Mercury photographs are completely reduced, Rear Admiral John Rodgers, Superintendent of the Naval Observatory, has kindly authorized me to make use of the results. They are as follows:

The total number of plates measured was 119, of which 25 were made at Cambridge, 30 at Washington, and 64 at Ann Arbor. Each plate was measured by two different persons. The errors to be considered are of four different kinds, namely: constant and accidental errors in measuring the plates, and constant and accidental errors peculiar to each station.

Each plate having been measured in duplicate, if the positions of Mercury upon the sun's disk given by the measures of the first observer are subtracted from those given by the measures of the second observer, the mean of all the residuals thus obtained will be the constant error due to personal equation in reading. Its amount for each station is

	In altitude.	In azimuth.
Cambridge	$-0''\cdot10$	$-0''\cdot08$
Washington	$-0\cdot09$	$+0\cdot08$
Ann Arbor	$+0\cdot15$	$-0\cdot02$

Thus it appears that, for the mean of the three stations, the constant error of reading is practically zero.

If the mean of the readings by the two observers is accepted as the truth, the probable error of the position of Mercury upon the sun's disk, as determined from a single set of readings by one observer, is

	In altitude.	In azimuth.
Cambridge	$\pm0''\cdot18$	$\pm0''\cdot20$
Washington	$\pm0\cdot19$	$\pm0\cdot18$
Ann Arbor	$\pm0\cdot24$	$\pm0\cdot28$

The locus of the average probable error of reading therefore lies within a circle whose radius is $0''\cdot21$.

The corrections found at each station to LeVerrier's tables of Mercury, as represented by the British Nautical Almanac for 1878, are

	R. A.	N. P. D.
Cambridge	$+0^s.079$	$-0''.22$
Washington	$+0.105$	-0.12
Ann Arbor	$+0.083$	$+0.47$

The correction to the north polar distance, given by the Ann Arbor plates, seems to be affected by a systematic error, but it is doubtful if its source can be discovered because no details of the observations were sent to the Naval Observatory, and Professor Watson, who made them, is now dead.

The probable error of a position of Mercury depending upon two sets of readings made upon a single photograph is

	R. A.	N. P. D.
Cambridge	$\pm 0''.570$	$\pm 0''.562$
Washington	± 0.655	± 0.579
Ann Arbor	± 0.436	± 0.514

The probable errors in right ascension having been reduced to arc of a great circle. We may infer from the mean of all the stations that the average locus of the probable error of the position of the planet in the heavens is a circle whose radius is $0''.553$.

To exhibit yet more clearly the degree of accuracy attained by the photographic method, a table is appended, which includes all the plates, and shows the number of residuals, both in right ascension and north polar distance, which fall between $0''.0$ and just under $0''.2$, $0''.2$ and just under $0''.5$, etc. In tabulating the right ascension residuals it has been assumed that $0''.2 = 0^s.01$, $0''.5 = 0^s.03$, $1''.0 = 0^s.07$, $1''.5 = 0^s.10$, $2''.0 = 0^s.13$.

Limits.	Cambridge.		Washington.		Ann Arbor.	
	R. A.	N. P. D.	R. A.	N. P. D.	R. A.	N. D. P.
$0''.0$–$0''.2$	3	5	3	7	11	11
0.2–0.5	5	6	5	6	16	14
0.5–1.0	10	7	11	10	29	27
1.0–1.5	5	4	8	3	5	7
1.5–2.0	0	2	2	1	3	5
2·0 and over	2	1	1	3	0	0

Theory of the Gravitational Methods.

We begin the consideration of the gravitational methods by deriving an expression for the solar parallax in terms of the earth's mass.

If l is the length of a simple pendulum which makes one vibration in t seconds of mean time, the observed force of gravity will be

$$G = \frac{\pi^2 l}{t^2} \tag{1}$$

The attraction of the earth at a point upon its surface in geocentric latitude φ is

$$\frac{k^2 E}{\rho_1^2} \tag{2}$$

The observed force of gravity is the earth's attractive force diminished by the resolved value of its centrifugal force. At the equator the centrifugal force is $G \div 289{\cdot}24$, while in any other latitude it is $G \cos\varphi \div 289{\cdot}24$; and the resolved part of this force acting in the direction of the vertical is $G \cos^2\varphi \div 289{\cdot}24$. Equating the earth's attraction to the force of gravity augmented by the centrifugal force, we have

$$\frac{k^2 E}{\rho_1^2} = G\left(1 + \frac{\cos^2\varphi}{289{\cdot}24}\right) \tag{3}$$

Whence, by (1)

$$\frac{k^2}{\pi^2} = \frac{\rho_1^2 l}{t^2 E}\left(1 + \frac{\cos^2\varphi}{289{\cdot}24}\right) \tag{4}$$

If T is the length of the sidereal year, expressed in seconds of mean time, and a_1 is that value of the semi-major axis of the earth's orbit which would satisfy Kepler's third law, we have

$$T^2 = \frac{4\pi^2 a_1^3}{k^2(S+E)} \tag{5}$$

Le Verrier has shown that $a = 1{\cdot}000141 a_1$, (OPM, ii, 60, and iv, 103). Substituting this value in (5), and transposing

$$\frac{k^2}{\pi^2} = \frac{4a^3}{T^2(S+E)(1{\cdot}000141)^3} \tag{6}$$

Eliminating k and π between (4) and (6), and rearranging the terms

$$\frac{S+E}{E} = \frac{4t^2 a^3}{l T^2 \rho_1^2 (1{\cdot}000141)^3\left(1 + \frac{\cos^2\varphi}{289{\cdot}24}\right)} \tag{7}$$

Owing to the equatorial bulging of the earth, the points which have $\sqrt{\frac{1}{3}}$ for the sine of their geocentric latitude are the only ones upon the surface of the earth at which a pendulum will vibrate as it would if the whole mass of the earth were concentrated at its center. For that reason we take $\sin^2\varphi = \frac{1}{3}$, and consequently $\cos^2\varphi = \frac{2}{3}$. We also put $\rho_1 = c\rho$, and $a \sin p = \rho$. Substituting these values in (7), it becomes

$$\frac{S+E}{E} = \frac{4t^2\varphi}{l T^2 c^2 \sin^2 p (1{\cdot}000141)^2 \left(\frac{434{\cdot}86}{433{\cdot}86}\right)} \qquad (8)$$

The equation $\sin^2\varphi = \frac{1}{3}$, gives $\varphi = 35^\circ\ 15'\ 52''$. Adding to this the angle of the vertical, $10'\ 51''$, the geographical latitude is $35^\circ\ 26'\ 43''$, and the corresponding value of log c is 9·999515. If we take $t = 1^s$, the value of l for latitude $35^\circ\ 26'\ 43''$ is 0·992732 meters.* Substituting these values, together with T = 31,558,149 seconds of mean solar time, and $\rho = 6{,}378{,}390$ meters, in equation (8), it becomes

$$p^3\left(\frac{S+E}{E}\right) = 226{,}350{,}000 \qquad (9)$$

or

$$p = 609{\cdot}434\sqrt[3]{\frac{E}{S+E}} \qquad (10)$$

where p is expressed in seconds of arc.

In connection with equations (9) and (10) the reader may compare "Hansen on the calculation of the sun's parallax from the lunar theory," MNt, 1864, vol. xxiv, p. 11; "Darlegung der theoretischen Berechnung der in den Mondtafeln angewandten Störungen, von P. A. Hansen." Zweite Abhandlung, s. 271; "E. J. Stone on the value of the solar parallax, as deduced from the parallactic inequality in the earth's motion." MNt, 1868, vol. xxviii, p. 23; Le Verrier, in the CRH, 1872, t. lxxv, p. 166, and MNt, 1872, vol. xxxii, p. 322.

The equation of the parallactic inequality of the moon's motion, as given by Newcomb from the theories of Plana and Delaunay, is

$$Q = 0{\cdot}24123\frac{1-M}{1+M} \times \frac{p}{\sin P\left(1-\frac{1}{6}m^2\right)} \qquad (11)$$

Substituting the numerical values of P and m, and transposing, this becomes

$$p = [8{\cdot}837088]\, Q\frac{1+M}{1-M} \qquad (12)$$

from which p can be found when Q and M are known. The quantity within the square brackets is the logarithm of the number which it represents.

In connection with equations (11) and (12) the reader may compare PTL, t. iii, p. 13; DTL, t. ii, p. 847, equation 342; WOb, 1865, Appendix 2, p. 24; MNt, 1880, vol. xl, p. 468.

The lunar equation of the earth's motion is (OPM, iv, 47)

$$\delta\nu = -\frac{M}{E+M} \times \frac{\sin p'}{\sin P'} \times \cos s' \sin(\nu' - \nu) \qquad (13)$$

* Everett, Units and Physical Constants, p. 21.

in which p' and P′ are the actual values of the solar and lunar parallaxes at the instant for which $\delta\nu$ is required. For any given lunation, $\delta\nu$ will evidently attain its maximum value when $\sin(\nu'-\nu)=1$, that is, when the longitudes of the sun and moon differ by ninety degrees. If now we have an extensive series of observed values of $\delta\nu$, covering many complete revolutions of the moon's node; $\delta\nu$ will have assumed all possible values, the mean of which will be the constant of the lunar inequality; p' will have assumed all possible values, the mean of which will be the constant of solar parallax; and the moon will have had all possible latitudes, the mean of which will be zero. With P′ the case will be somewhat different. It is equal to the constant of lunar parallax, plus a series of terms multiplied by factors made up of the mean anomaly of the sun, the mean anomaly of the moon, the mean distance of the moon from its ascending node, and the difference of the mean longitudes of the sun and moon. All these terms, except those involving the difference of the mean longitudes, will assume all possible values and vanish from the mean. The mean of all the values of P′ will therefore be, P + terms depending upon the difference of mean longitudes of the sun and moon.* Turning now to the second volume of Delaunay's theory of the moon, we find that the only term of this kind in the lunar parallax is the one numbered (27), upon page 917, and its value is $28''\cdot1788 \cos 2D$. As we have supposed all our observations of $\delta\nu$ to be made when D was 90°, the value of this term will be $-28''\cdot18$, and the mean value of P′ will be $P-28''\cdot18 = 3394''\cdot52$. Substituting the mean values thus found in (13), and rearranging the terms, we obtain

$$p = 0\cdot0164564\, L\left(\frac{E+M}{M}\right) \qquad (14)$$

In connection with equation (14) the reader may compare, Le Verrier, OPM, iv, 100; Newcomb, WOb, 1855, App. II p. 28; E. J. Stone, MNt, 1868, vol. xxviii, p. 24.

The Moon's Mass.

Before the solar parallax can be obtained from equations (12) and (14), it is necessary to know the moon's mass. Let us consider the different ways of determining it.

The first determination of the moon's mass was made from the tides, by Newton, in 1687. Since then other investigators have employed the same method, but owing to the theoretical and practical difficulties inherent in it, their results have been so discordant as to command very little confidence. Perhaps

* In strictness it should be the difference of the *true* longitudes of the sun and moon.

the most trustworthy result is that by Mr. Wm. Ferrel of the United States Coast Survey, who found the moon's mass from the tides at Brest $\frac{1}{77.14}$, and from the tides at Boston $\frac{1}{78.64}$, the most probable mean being $\frac{1}{77.5}$. (Jour. Frank. Inst., 1871, vol. lxi, p. 366.)

In 1755, D'Alembert determined the moon's mass from the phenomena of precession and nutation, but to do this with extreme accuracy seems a difficult matter. The most recent attempt is by Mr. E. J. Stone (MNt, 1868, vol. xxviii, p. 43), who considers that his equations are accurate to terms of the third order in the lunar theory. With some changes of notation, they are

$$\left.\begin{aligned} \varepsilon &= \frac{\mathrm{M}a^3}{\mathrm{S}a_1^3} \\ \Psi &= \mathrm{A}\varkappa + \mathrm{B}\varkappa\varepsilon \\ \Omega &= \mathrm{C}\varkappa\varepsilon \end{aligned}\right\} \tag{15}$$

in which

$$\left.\begin{aligned} \mathrm{A} &= 1+\frac{3e_1^2}{2} \\ \mathrm{B} &= 1+\frac{3e^2}{2}-6\gamma^2 \\ \mathrm{C} &= \frac{2\gamma}{\mu}\left(1+\frac{e^2 3}{2}-\frac{5\gamma^2}{2}\right) \end{aligned}\right\} \tag{16}$$

Elimiting $\varkappa$ and ε from the equations (15), and introducing the sines of the parallaxes instead of the mean distances, we get

$$\mathrm{M} = \frac{\sin^3 p.\mathrm{A}\Omega\mathrm{S}}{\sin^3 \mathrm{P}\,(\mathrm{C}\Psi - \mathrm{B}\Omega)} \tag{17}$$

which becomes

$$\mathrm{M} = \frac{[2{\cdot}411505]\,\mathrm{A}\Omega}{\sin^3 \mathrm{P}\,(\mathrm{C}\Psi - \mathrm{B}\Omega)} \tag{18}$$

by substituting the value of $\mathrm{S}\sin^3 p$ from (9). The number within the square brackets is the logarithm of the quantity which it represents. Ten must be subtracted from its characteristic.

We will take

$$\begin{aligned} \gamma &= 0{\cdot}04488663 \\ e &= 0{\cdot}0548993 \\ e_1 &= 0{\cdot}0167711 \\ \mu &= -19^\circ\,21'\,20'' = -0{\cdot}337818 \text{ of radius.} \\ \mathrm{P} &= 3422''{\cdot}7 \end{aligned}$$

The value here given for e is that used by Delaunay (DTL, ii, 802). The value of P is that found from the Greenwich and Cape of Good Hope observations by Breen (MAS, 1864, vol. xxxii, p. 137) and E. J. Stone (MAS, 1866, vol. xxxiv, p. 16). Substituting these values in (16) and (18), the latter equation becomes

$$\frac{1}{M} = 47{\cdot}0243\,\frac{\Psi}{\Omega} - 175{\cdot}705 \qquad (19)$$

In connection with equations (18) and (19), the reader may compare PTL, t. iii, pp. 25–29; LeVerrier, OPM, t. iv, p. 101; Serret, OPM, v, 324; Newcomb, WOb, 1865, App. II, p. 28.

About 1795 Delambre seems to have determined the moon's mass from the lunar inequality of the earth's motion. This involves the use of equation (14), but as we propose to employ that equation for determining the solar parallax, we cannot avail ourselves of it for the mass of the moon.

There is yet another way of determining the moon's mass; to wit, by comparing the fall of heavy bodies at the surface of the earth with the fall of the moon in its orbit. The resulting equation will be similar to (8), except that for the masses of the sun and earth we must substitute the masses of the earth and moon, and instead of $1{\cdot}000141 \sin p$ we must employ the particular value of P which satisfies equation (5) when E+M is substituted in it for S+E, and T is taken to be the length of a sidereal revolution of the moon, expressed in seconds of mean time. Designating these special values of T and P by T_1 and P_1, we have

$$\frac{E+M}{M} = \frac{4\ell^2\rho}{l T_1^{\,2} c^2 \sin^3 P_1 \left(\frac{434{\cdot}86}{433{\cdot}86}\right)} \qquad (20)$$

Of the four methods just described for determining the moon's mass, that depending upon the tides is not sufficiently accurate, and that depending upon the lunar inequality of the earth's motion is not available, for our purpose. There remain only the two methods represented respectively by equations (19) and (20). Let us see what results they give.

As the luni-solar precession increases continually with the time, its value is now known very accurately. I adopt for it the numbers used by Messrs. Newcomb and Stone (WOb, 1865, App. II, p. 28; MNt, 1868, vol. xxviii, p. 43), namely $50''{\cdot}378$. The constant of nutation is much more uncertain. The following are some of the best modern values:

1842. C. A. F. Peters (Num. Con. Nut., p. 37), ... $9''{\cdot}223$
1844. C. A. F. Peters (Mem. Ac. Sc. St. Petersbourg, 7e sér. t. iii, p. 125), ... $9{\cdot}216$

1856. LeVerrier (OPM, t. ii, p. 174),	9·23
1869. E. J. Stone (MAS. vol. xxxvii, p. 249),	9·134
1872. Nyrén (Mem. Ac. Sc. St. Petersbourg, 7e sér. t. xix, No. 2),	9·236

With $\mathit{F}=50''\cdot378$, formula (19) gives the mass of the moon corresponding to three different values of the nutation constant as follows:

$$\Omega = 9''\cdot230 \quad \mathrm{M} = \frac{1}{80\cdot96}$$

$$\Omega = 9''\cdot223 \quad \mathrm{M} = \frac{1}{81\cdot15}$$

$$\Omega = 9''\cdot134 \quad \mathrm{M} = \frac{1}{83\cdot65}$$

The change in the moon's mass produced by a small change in the constant of nutation is given by the expression

$$d\left(\frac{1}{\mathrm{M}}\right) = -\,28\cdot1\,d\Omega \qquad (21)$$

In view of the fact that Peters attributed a probable error of $\pm 0''\cdot0154$ to his most careful determination of the nutation constant, and in view of the subsequent widely differing determination by E. J. Stone, it can scarcely be supposed that the true value of the nutation is known within $\pm 0''\cdot02$. This corresponds to an uncertainty of $\pm 0\cdot56$ in the reciprocal of the moon's mass.

The length of the sidereal month is 2,360,591·8 seconds of mean solar time. Assuming the observed value of the constant of lunar parallax to be $3422''\cdot7$, Plana's theory gives $3419''\cdot62$, and Delaunay's theory $3419''\cdot59$, for the value of P_1. I adopt $3419''\cdot6$. Substituting these values in formula (20), the resulting mass of the moon is $\frac{1}{81\cdot77}$, and the change in the mass produced by a small change in the adopted parallax is given by the expression

$$d\left(\frac{1}{\mathrm{M}}\right) = 5\cdot925\,d\mathrm{P} \qquad (22)$$

The value of the lunar parallax now generally adopted, depends upon the investigations of Messrs. Breen and E. J. Stone. The results of these two gentlemen agree within $0''\cdot01$. The probable error of Mr. Breen's result is not stated, while that of Mr. Stone's is $\pm 0''\cdot049$. Nevertheless, it is not unlikely that the parallax may be one or two-tenths of a second in error. An error of $0''\cdot1$ would produce an error of 0·59 in the reciprocal of the mass.

Probably the moon's mass is about $\frac{1}{81{\cdot}5}$, but it is quite possible that this estimate may be in error by one part in a hundred. The precession-nutation method is considered one of the best for obtaining the moon's mass, but equations (21) and (22) show that neither it, nor the method by the fall of the moon in its orbit, is likely ever to furnish the mass within one part in a thousand. Throughout all his lunar work Hansen adopted a mass of $\frac{1}{80}$, and in what follows I will assume that the true mass lies between the limits $\frac{1}{80}$ and $\frac{1}{83}$.

Parallax from Gravitational Methods.

Mass of the Earth.—In 1872 LeVerrier obtained the mass of the earth from the inequalities in the motions of Venus and Mars, and the secular variations in the elements of their orbits, produced by it; and from the mass thus found he derived the solar parallax by means of an equation similar to (10). (CRH, 1872, t. lxxv, pp. 165–172; MNt, 1872, vol. xxxii, pp. 322–328.) He gave the resulting parallaxes without directly stating the masses, but it is readily seen that his values were as follows:

(A). From the latitudes of Venus at the moments of the transits in 1761 and 1769, earth's mass $= \frac{1}{325{,}165}$.

(B). From a discussion of the meridian observations of Venus in an interval of one hundred and six years, earth's mass $= \frac{1}{324{,}575}$.

(C). From observations of the occultation of ψ^3 Aquarii by Mars, October 1st, 1672, earth's mass $= \frac{1}{323{,}746}$.

Substituting these values in equation (10), the resulting values of the solar parallax are

A.	$8''{\cdot}862$
B.	$8{\cdot}868$
C.	$8{\cdot}875$

Taking the earth's mass as unity, the change in the parallax produced by a change of one thousand units in the mass of the sun is given by the expression

$$dp = 0{\cdot}00912\, d\mathrm{S} \qquad (23)$$

It is difficult to estimate the probable error of the above values of the earth's mass, but Tisserand seems to think it

may be sufficient to affect the parallax by $\pm 0''{\cdot}07$. (CRH, 1881, t. xcii, p. 658.) As the secular variations of the elements of the orbits of Venus and Mars increase continually, they will ultimately attain sufficient magnitude to give a very exact value of the earth's mass, and then this method will furnish the solar parallax with the utmost precision.

Parallactic Inequality.—Professor Newcomb found that the value of the parallactic inequality of the moon deduced by Hansen from the Greenwich and Dorpat observations is $126''{\cdot}46$. (WOb, 1865, App. II, p. 23.)

From 2075 Greenwich lunar observations, made between 1848 and 1866, Mr. E. J. Stone found the parallactic inequality to be $125''{\cdot}36 \pm 0''{\cdot}4$; the probable error being estimated. (MNt, 1867, vol. xxvii, p. 271.)

From the Washington lunar observations, made between 1862 and 1865, Professor Newcomb found the parallactic inequality to be $125''{\cdot}46$. (WOb, 1865, App. II, p. 24.)

From an extended discussion of the whole subject, published in the MNt, 1880, vol. xl, pp. 386 to 411, and 441 to 472, Messrs. Campbell and Neison found the observed value of the parallactic inequality to be (p. 467) either $125''{\cdot}64 \pm 0''{\cdot}09$, or $124''{\cdot}64 \pm 0''{\cdot}25$; the difference arising from the admission or non-admission into the lunar theory of a certain hypothetical forty-five year term.

By substituting these values of Q in equation (12) the following values of the solar parallax result:

Moon's Mass.	$\frac{1}{80}$	$\frac{1}{81}$	$\frac{1}{82}$	$\frac{1}{83}$
Q = 124″·64	8″·782	8″·780	8″·778	8″·776
125·36	·833	·831	·829	·827
125·46	·839	·837	·835	·833
125·64	·851	·849	·847	·845
126·46	8·910	8·908	8·906	8·904

These parallaxes are but little affected by the assumed mass of the moon, and depend almost entirely upon the observed value of the parallactic inequality, the relation between small changes of p and Q being

$$dp = 0{\cdot}071\, dQ \qquad (24)$$

The original observed values of Q are affected by personal equation, irradiation, blurring, and any error which may exist in the adopted semi-diameter of the moon. It is difficult to estimate how thoroughly these quantities are eliminated from the final result, but the remaining uncertainty probably amounts to a considerable fraction of a second.

Lunar Inequality of the Earth.—From observations at Greenwich, Paris and Kœnigsberg, made during the periods stated, LeVerrier found the following values for the lunar equation of the earth: (OPM, iv, 100)

Greenwich	1816–26	L = 6″·45
"	1827–50	6·56
Paris	1804–14	6·61
"	1815–45	6·47
Kœnigsberg	1814–30	6·43

The mean is 6″·50±0″·023.

Professor Newcomb found the following additional values: (WOb, 1865, App. II, pp. 25 and 26)

Greenwich	1851–64	L = 6″·56±0″·04
Washington	1861–65	6·51 ±0·07

With these values of L, equation (14) furnishes the following values of the solar parallax:

Moon's Mass.	$\frac{1}{80}$	$\frac{1}{81}$	$\frac{1}{82}$	$\frac{1}{83}$
L = 6″·50	8″·664	8″·770	8″·878	8″·985
6·51	·678	·784	·892	8·999
6·56	8·744	8·851	8·960	9·068

It would seem that the observed value of L should be quite free from systematic errors, because it depends upon observations of the sun which are always made in the same way. The relation subsisting between small changes in the parallax, the mass of the moon, and the earth's lunar inequality, are given by the equation

$$dp = 1{\cdot}36\, d\mathrm{L} + 0{\cdot}107\, d\left(\frac{1}{\mathrm{M}}\right) \qquad (25)$$

It will be difficult to determine the true value of L within ±0″·02, and at present the uncertainty in the reciprocal of the moon's mass is at least ±0·5. With these data the probable error of p comes out ±0″·06.

Photo-tachymetrical Methods.

Theory.—The photo-tachymetrical methods are quite recent, having come into existence about 1850, when Fizeau and Foucault made their inventions for measuring the velocity with which light traverses moderate distances upon the surface of the earth. From the velocity of light thus obtained the solar parallax may be found by two essentially different methods, to wit:

1st. Deriving from the eclipses of Jupiter's satellites the time occupied by light in traversing the mean distance between the

earth and the sun, and combining this with the measured velocity of light, we have

$$\tan p = \frac{\rho}{V\theta} \tag{26}$$

2d. Assuming the ratio of the earth's orbital velocity to the velocity of light to be represented by the constant of aberration, and combining that constant with the measured velocity of light, we have

$$\tan p = \frac{2\pi\rho}{TV \tan \alpha \sqrt{1-e^2_1}} \tag{27}$$

If p and V are eliminated between (26) and (27) we get

$$\tan \alpha = \frac{2\pi\theta}{T\sqrt{1-e^2_1}} \tag{28}$$

which shows the relation between α and θ.

For the constants in these equations I adopt

$\rho = 6378{\cdot}39$ kilometers (Col. Clarke's value).
$T = 31{,}558{,}149$ seconds of mean time.
$e_1 = 0{\cdot}016771$

and the equations become

$$p = \frac{[9{\cdot}11914]}{\theta V} \tag{29}$$

$$p = \frac{[7{\cdot}73269]}{\alpha V} \tag{30}$$

$$\theta = [1{\cdot}38644]\alpha \tag{31}$$

the quantities within the square brackets being the logarithms of the numbers which they represent. In connection with equations (26), (27), (28), the reader may consult Cornu, OPM, t. xiii, pp. A 299–A 301.

Velocity of Light.—The following are the principal experimental determinations of the velocity of light between points upon the earth's surface:

	Kilometers.
1849. Fizeau (CRH, 1849, t. xxix, p. 90),	315,320
1862. Foucault (CRH, 1862, t. lv, p. 796: Recueil des travaux scientifiques de Léon Foucault, pp.216–226),	298,000
1874. Cornu (OPM, xiii, 293),	300,400
1876. Helmert (ANn, 1876, bd. lxxxvii, s. 126),	299,990
1879. Michelson (Proc. Amer. Assoc., 1879, pp. 124–160),	299,940
1881. Young and Forbes (Nature, 1881, vol. xxiv, p. 303),	301,382

Light Equation.—The time taken by light to traverse the mean radius of the earth's orbit is commonly called the light equation, and there are but two determinations of it from the eclipses of Jupiter's satellites, namely:

1792. Delambre, from more than a thousand eclipses of the first satellite (Astronomie par Jerome le Français (la Lande), 3me edition. Paris, 1792, t. i, Tables astronomiques, p. 238. Also, Tables Ecliptiques des Satellites de Jupiter, par M. Delambre. Paris, 1817, p. vii,.....493s·2

1874. Glasenapp (Investigation of the eclipses of Jupiter's satellites. A dissertation for the degree of master of astronomy, by S. Glasenapp. Published in the Russian language, at St. Petersburg, 1874, p. 131),.....500·84

Glasenapp considered the probable error of his determination to be ±1s·02.

Aberration.—The following are the principal determinations of the coefficient of aberration :

1728. Bradley (PTr, 1728, p. 655),.....20″·25
1821. Brinkley (PTr, 1821, p. 350),.....20·37
1840. Henderson (MAS, 1840, xi, 248),.....20·41
1843. W. Struve (ANn, 1843, bd. xxi, s. 58),.....20·445
1844. C. A. F. Peters (ANn, 1844, bd. xxii, s. 119),.....20·503
1850. Maclear (MAS, 1851, vol. xx, p. 98),.....20·53
1861. Main (MAS, 1861, vol. xxix, p. 190),.....20·335

Solar Parallax.—The table below exhibits the various values of the solar parallax deducible from the foregoing values of V, θ and α by means of equations (29) and (30). I have rejected Fizeau and Foucault's values of the velocity of light on the ground that they are merely first approximations, the details of which have never been published; and I have made no use of Helmert's rediscussion of Cornu's value. The last column of the table gives the values of α and θ computed by means of equation (31) from the values of θ and α in the first column.

Velocity of Light....	299,940	300,400	301,382	
Light equa'n				Aberration
493s·20	8″·894	8″·880	8″·851	20″·26
500·84	8·758	8·745	8·716	20·57
Aberration				Light equa'n
20″·25	8″·897	8″·883	8″·854	493s·02
·335	·860	·846	·817	495·09
·37	·844	·831	·802	495·94
·41	·827	·814	·785	496·91
·445	·812	·799	·770	497·76
·503	·787	·773	·745	499·19
20·53	8·775	8·762	8·734	499·84

The relations between small changes in p, θ, α, and V, are given by the equations

$$dp = -0{\cdot}0177\, d\theta - 0{\cdot}0295\, d\mathrm{V} \qquad (32)$$

$$dp = -0{\cdot}432\ d\alpha - 0{\cdot}0295\, d\mathrm{V} \qquad (33)$$

where θ is in seconds of mean time, α in seconds of arc, and V in thousands of kilometers. To determine p with a probable error not exceeding $\pm 0''{\cdot}01$, the probable errors of the other quantities must not exceed the following values, namely: θ, $\pm 0^{s}{\cdot}40$, and V, ± 240 kilometers; or α, $\pm 0''{\cdot}016$, and V, ± 240 kilometers. Whatever may be said respecting V, it is quite certain that our present knowledge of θ and α does not approach this degree of accuracy. The probable error of p seems to be at least $\pm 0''{\cdot}05$.

The photo-tachymetric method is embarrassed by serious theoretical difficulties. 1st. As we are ignorant of the optical constitution of inter-planetary space, we have no sure means of passing from the velocity of light at the earth's surface to its velocity in space. 2d. There is no rigorous proof that the constant of aberration gives the exact ratio of the velocity of light to the earth's orbital velocity. 3d. The velocity of light is the velocity of transmission of a single wave, while Fizeau's and Foucault's methods determine the velocity of transmission of a group of waves. Lord Rayleigh has shown that these two things are not necessarily the same. If the ordinary theory of aberration is accepted the velocity of light to which it refers is the velocity of a single wave, while the velocity determined from the eclipses of Jupiter's satellites is that of a group of waves. (Nature, 1881, vol. xxiv, pp. 382 and 460.)

Respecting the theory of aberration the reader may consult, Ann. de Chimie et de Physique, 1818, t. ix, p. 57; Oeuvres completes d'Augustin Fresnel, t. ii, p. 627; Stokes, in L. E. and D. Phil. Mag. 1845, vol. xxvii, p. 9; 1846, vol. xxviii, p. 76; 1846, vol. xxix, p. 6; Klinkerfues, in ANn, 1866, bd. lxvi, s. 337; 1868, bd. lxx, s. 239; 1870, bd. lxxvi, s. 33; Sohncke, ANn, 1867, bd. lxix, s. 209; Hoek, ANn, 1867, bd. lxx, s. 193; Veltmann, ANn, 1870, bd. lxxv, s. 145; Airy, Greenwich Observations, 1871, p. cxix; Proceed. Roy. Soc. 1873, vol. xxi, p. 121; Villarceau, Conn. de Temps, 1878, Additions; Michelson, this Journal, 1881, vol. xxii, p. 120.

Conclusion.

For convenience of reference the limiting values of the solar parallax, found by the various methods described in the foregoing pages, are presented here. It should be remarked, however, that in selecting these values the results of all discussions

made prior to 1857 have been omitted; except in the case of the transit of 1761, and the smaller of the two values from the transit of 1769.

I.—Trigonometrical methods.

Mars, meridian observations	8″·84 — 8″·96
" diurnal observations	8·60 — 8·79
Asteroids	8·76 — 8·88
Transit of Venus, 1761	8·49 — 10·10
" " 1769	8·55 — 8·91
" " 1874	8·76 — 8·85

II.—Gravitational methods.

Mass of the earth	8″·87 ± 0″·07
Parallactic Inequality	8·78 — 8·91
Lunar Inequality	8·66 — 9·07

III.—Photo-tachymetrical methods.

Velocity and Light Equation	8″·72 — 8″·89
Velocity and Aberration	8·73 — 8·90

To obtain a definitive value of the solar parallax, it would now be necessary to form equations of condition embodying the relations between the various elements involved; to weight these equations; and to solve for p by the method of least squares. But what is the use? It is perfectly evident that by adopting suitable weights, almost any value from 8″·8 to 8″·9 could be obtained; and no matter what the result actually was, it would always be open to a suspicion of having been cooked in the weighting. We only know that the parallax seems to lie between 8″·75 and 8″·90, and is probably about 8″·85. Attack the problem as we will, the results cluster around this central value. All the methods give a probable error of about ±0″·06, and no one of them seems to possess decided superiority over the others. We have nearly exhausted the powers of our instruments, and further advance can only be made at the cost of excessive labor.

In the beginning of the eighteenth century the uncertainty of the solar parallax was fully two seconds; now it is only about 0″·15. To narrow it still further, we require a better knowledge of the masses of the earth and moon, of the moon's parallactic inequality, of the lunar equation of the earth, of the constants of nutation and aberration, of the velocity of light, and of the light equation. All these investigations can be carried on at any time, but there are others equally important which can only be prosecuted when the planets come into the requisite positions. Among the latter are observations of Mars when in opposition at its least distance from the earth, and transits of Venus.

In 1874 all astronomers hoped and believed that the transit of Venus which occurred in December of that year would give the solar parallax within 0″·01. These hopes were doomed to disappointment, and now, when we are approaching the second transit of the pair, there is less enthusiasm than there was eight years ago. Nevertheless, the astronomers of the twentieth century will not hold us guiltless if we neglect in any respect the transit of 1882. Observations of contacts will doubtless be made in abundance, but our efforts should not cease with them. We have seen that the probable error of a contact observation is ±0″·15, that there may always be a doubt as to the phase observed, and that a passing cloud may cause the loss of the transit. On the other hand, the photographic method cannot be defeated by passing clouds, is not liable to any uncertainty of interpretation, seems to be free from systematic errors, and is so accurate that the result from a single negative has a probable error of only ±0″·55. If the sun is visible for so much as fifteen minutes during the whole transit, thirty-two negatives can be taken, and they will give as accurate a result as the observation of both internal contacts. In view of these facts, can it be doubted that the photographic method offers as much accuracy as the contact method, and many more chances of success?

The transit of 1882 will not settle the value of the solar parallax, but it will contribute to that result, directly as a trigonometrical method, and indirectly through the gravitational methods with which the final solution of the problem must rest. As our knowledge of the earth's mass may be made to depend upon quantities which continually increase with the time, it will ultimately attain great exactness, and then the solar parallax will be known with the same exactness. Long before that happy day arrives the present generation of astronomers will have passed over to the silent majority, but not without the satisfaction of knowing that their labors will contribute to that fullness of knowledge which shall be the heritage of their successors.

Washington, D. C., October, 1881.

ART. LIII.—*On the Nature of Cyathophycus;* by C. D. WALCOTT.

THIS genus was originally described by me under the impression that the form was an alga of a peculiar appearance.* On reading the observations of Professor R. P. Whitfield, on the nature of Dictyophyton and its affinities to certain sponges,† it was instantly suggested that Cyathophycus was probably a member of the same group. A special effort was

* Trans. Albany Institute, vol. x, 1879. † This Journal, xxii, July, Aug., 1881.

made to obtain perfectly preserved specimens of the genus, and with such success that the reticulate structure mentioned in the original description was found to be formed of a horizontal and perpendicular series of narrow bands crossing each other at right angles so as to form a network with rectangular interspaces, the narrow bands being formed of thread-like spiculæ resting on, or one against the other. The spiculæ differ in size; some are filiform while others are stronger and more prominent, and all appear to be replaced by pyrite as in the Devonian specimens studied by Principal Dawson and Professor Whitfield. Through the kindness of Professor Whitfield I have had the opportunity of examining the specimens referred to by him, and now have little doubt but that the Utica slate form belongs to the same class, although probably differing generically from the Devonian species, and is an earlier representative of this interesting group of sponges.

Cyathophycus reticulatus presents a beautiful appearance when a large number of specimens are flattened out on a slab of the dark slate. Each individual lays free from its associates and the striking resemblance to *Euplectella* is seen at a glance, although the convex summit of the latter genus is absent and the margin curves over and downward on the inside to a considerable distance at least, how far is yet unknown. The cylindrical forms vary in length from 10 to 350^{mm}, and the spheroidal species, *C. subsphericus*, from 3 to 60^{mm} in diameter, each species preserving the rounded rim of the circular aperture at the summit.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *International Congress of Electricians.* (Letter from Professor G. F. Barker, of the United States Delegation, dated Paris, Oct. 1st, 1881.)—My duties here as Commissioner, as Delegate, and now as a member of the Jury, have been, and still are, so pressing that I have been obliged to forego letter writing almost entirely. I have tried too, to put together some points of interest for the readers of the Journal, but have thus far been quite unable to complete anything.

The Exhibition as a whole has been a decided success. It has brought together an immense mass of highly interesting material. There are in all something over 1500 exhibitors, of which one half are French, 155 Belgian, 115 English, 114 German, 81 Italian, 72 American, 39 Austrian, 32 Russian, 21 Swedish, 13 Swiss, 17 Spanish, 13 Norwegian, 11 Dutch, 5 Danish, and 2 Japanese. Of decided novelties, there are more in the United States section

than in any other. Edison has made a wonderful exhibition of his inventions and his rooms are thronged continually. The principle discovered by him that an electric current varies friction, the so-called motograph principle, together with the applications of it practically, are beautifully illustrated. The principle of the varying resistance of bodies which imperfectly conduct, when they are subjected to pressure, a principle which he was the first to investigate and to apply, is exhibited in a large series of instruments, one set of which traces the progress of development of the carbon telephone. The system of incandescent lighting which he has perfected is shown in all its details, from the unique dynamo-machine of low resistance and high electromotive force, the street conductors with their connections, safety-catches, expansion-caps, etc., the ingenious meter and the house conductors with their incombustible covering, to the fixtures with double conductors and safety catches, and lastly to the incandescent lamp itself. Dolbear exhibits a new electro-static telephone which performs admirably and which consists simply of two thin metal plates, connected to the secondary wire by an induction coil. They are oppositely charged by the coil and so attract each other. Gray's harmonic multiple telegraph is in successful operation and Bell's original photophone is also exhibited. The most original thing exhibited in the French section is the secondary battery; Planté exhibits several forms of it, Faure shows the improvement which he made by covering the plates with minium, and lastly Meritens is working a still newer form, in which only lead plates are used, but a large number of them are put in a small space. In the historical line the collection in the Exhibition is unrivaled. The pile of Volta, the electroscopes of Galvani, the thermopiles of Nobili and Melloni, the electro-magnetic induction ring of Faraday, the first magneto-machine of Pixii, the rheostats and telegraphs of Wheatstone, the telegraphs of Sœmmering, of Steinheil and of Gauss and Weber, the continuous current-machine of Pacimotti, the electro-thermic and electro-motor apparatus of Becquerel, the electro-capillary apparatus of Lippmann; all these and many more are here collected. And as for arc lights, the Exhibition at night is like day. The Brush machine and light are in great favor. A large lamp of this sort just put up has carbons two inches in diameter, and is claimed to give a light of 80,000 candles.

2. *Elasticity and Motion.*—Sir W. Thomson is led from the consideration of various experiments with fluids and solids and the study of smoke rings to speculate upon elasticity as an evidence of motion. The kinetic theory of gases requires that the molecule or atom shall be elastic. "But this kinetic theory of matter is a dream and must remain so until it can explain chemical affinity — electricity, magnetism, gravitation and inertia." The writer looks forward to a greater generalization which shall include elasticity as a form of motion.—*Roy. Inst. of Great Britain*, March, 1881. J. T.

3. *Efficiency of Spectroscopes.*—F. LIPPICH discusses the point whether it is more advantageous to increase the dispersion or to increase the magnifying power of the telescopes of a spectroscope. A mathematical discussion of the subject is given and the following conclusion is reached: The common impression that it is better to increase the dispersion instead of the magnifying power of the telescope is true only when the number of prisms does not exceed a certain number (from four to five). The author has constructed a spectroscope of two flint glass prisms, through which the light passes twice, provided with a telescope of magnifying power from fifty to seventy times, which excels in its performance that of a spectroscope of from twenty to twenty-eight flint glass prisms which has a telescope which magnifies only ten times. Seven lines are seen with the author's spectroscope between the D lines.—*Central-Zeit. f. Opt. u. Mech.*, 49 and 61, 1881.

J. T.

4. *Niagara Falls as a source of Energy.*—Sir WM. THOMSON thus sums up, in his British Association Address, the conclusions he has reached in regard to the utilization of the energy of Niagara Falls.

"1. Apply dynamos driven by Niagara to produce a difference of potential of 80,000 volts between a good earth connection and the near end of a solid copper wire of half an inch (1·27 centimeters) diameter, and 300 statute miles (483 kilometers) length.

"2. Let resistance by driven dynamos doing work, or by electric light, or, as I can now say, by a Faure battery taking in a charge, be applied to keep the remote end at a potential differing by 64,000 volts from a good earth plate there.

"3. The result will be a current of 240 webers through the wire taking energy from the Niagara end at the rate of 26,250 horse power, losing 5,250 (or 20 per cent) of this by the generation and dissipation of heat through the conductor and 21,000 horse power (or 80 per cent of the whole) on the recipients at the far end.

"4. The elevation of temperature above the surrounding atmosphere, to allow the heat generated in it to escape by radiation and be carried away by connection is only about 20° Centigrade; the wire being hung freely exposed to air like an ordinary telegraph wire supported on posts.

"5. The striking distance between flat metallic surfaces with difference of potentials of 80,000 volts (or 5,000 Daniells') is only eighteen millimeters, and therefore there is no difficulty about the insulation.

"6. The cost of the copper wire, reckoned at 8d. per pound, is 37,000*l.*, the interest on which at five per cent is 1900*l.* a year. If 5,250 horse power at the Niagara end costs more than 1900*l.* a year, it would be better economy to put more copper into the conductor; if less, less."—*Nature, Sept.* 8, 1881, p. 435. J. T.

5. *Change of plane of polarization of Heat rays by Electromagnetism.*—LEO GRUNMACH reviews the work of previous experimenters and arrives at the following conclusions:

(1.) A change of the plane of polarization of the heat rays can be produced in solid and fluid bodies by electromagnetism.

(2.) The magnitude of this change is different for different substances. The rotation is greater the greater the index of refraction of the substance.

(3.) The magnitude of the rotation in diathermanous bodies is proportional to the intensity of the current.

(4.) The magnitude of the rotation in a diathermanous body, placed between the poles of a magnet, is proportional to the magnetic force employed.

(5.) It also increases with the length of the layer of the substance: but this relation can not be computed from the length of the layer.—*Ann. der Physik und Chemie*, No. 9, 1881, p. 85. J. T.

6. *Electro dynamic-Balance.*—H. HELMHOLTZ provides an ordinary balance with two spirals of copper wire, in place of the pans. Beneath these spirals are also two spirals of larger radius. The terminals of these spirals are so arranged that one of the movable spirals is attached and the other repelled. The conditions of sensibility are discussed and the author concludes that the current which is equilibrated by one gram can be measured to $\frac{1}{2000}$ of its value.—*Ann. der Physik und Chemie*, No. 9, 1881, p. 52. J. T.

7. *Change of the thermo-electric condition of iron and steel by magnetization.*—V. STROUHAL and C. BARUS confirm the observation of Sir W. Thomson that a longitudinally magnetized iron wire is thermo-electrically more positive than a non-magnetic iron wire. Their results show that the changes in the thermo-electric condition of iron can not be used to indicate the hardness of the iron or steel. The thermo-electric current between pieces of iron of different magnetic conditions flows in the opposite direction from that which arises between pieces of different degrees of hardness. In other words it flows from the better conductor to the worse conductor.—*Ann. der Physik und Chemie*, No. 9, 1881, p. 54. J. T.

8. *Principles of Chemical Philosophy;* by JOSIAH PARSONS COOKE, Erving Professor of Chemistry and Mineralogy in Harvard College. Revised edition, 623 pp., 8vo. Boston, 1881, (John Allyn).—The first edition of Professor Cooke's valuable work on Chemical Philosophy was published in 1868. The years which have elapsed since then have brought fewer radical changes in the philosophy of chemical phenomena than those which immediately preceded, but the advances which have been made are hardly less important. The new edition is written from this advanced standpoint, and while it contains all the excellent features of the former it embraces also much that is valuable and new. The student who will faithfully read the successive chapters, and together with that, work out the many practical problems, cannot fail to gain a clear, connected and logical knowledge of the fundamental principles in chemical philosophy.

9. *A Manual of Sugar Analysis*, including the applications in general of the analytical methods to the Sugar Industry, with an Introduction on the Chemistry of Cane-sugar, Dextrose, Levulose

and Milk-sugar, by J. H. TUCKER, Ph.D. 353 pp. 8vo. New York, 1881 (D. Van Nostrand).—In consideration of the great importance of the sugar industry it is a matter of surprise that up to this time the various topics connected with the analytical portions of the subject have never been systematically discussed in any single volume in the English language. This deficiency the author has aimed to fill. The opening chapters of his work are devoted to the chemistry of the several kinds of sugar. Following these the methods used in the examination of sugars are described; first the determination of the specific gravity, then the optical method of study, and finally the chemical methods. The last are extended over a series of chapters giving the method of analysis of raw sugar, of molasses and syrup, of cane and cane juice, beet and beet juice, of the waste products, of glucose or starch sugar, and so on. The concluding chapters are devoted to the chemistry of animal charcoal. The book contains a large amount of useful information which will be hardly found elsewhere in so convenient a form.

II. GEOLOGY AND MINERALOGY.

1. *Report on the Geology and Resources of the Black Hills of Dakota;* by HENRY NEWTON and WALTER P. JENNEY. U. S. Geogr. and Geol. Survey of the Rocky Mountain Region, J. W. Powell in charge. 566 pp. 4to, with an atlas folio, 18 plates, in 4to, and many wood-cuts. Washington, 1880. (Copy of the work received in September, 1881.)—The Geological Report, which occupies two hundred pages of this volume, is based on the observations of Mr. Henry Newton, made in 1875, in accordance with instructions from the Secretary of the Interior, and was prepared for the press from his nearly finished manuscript by Professor Jenney. Mr. Newton was a graduate of the School of Mines of Columbia College, New York; and the volume opens with a biographical sketch, by Professor Newberry of that School, of the young geologist, who died in 1877, while engaged in a second but private visit to the region for further explorations. The Report contains, after its historical introduction, a careful description of the successive formations of the region, which include besides the Archæan and volcanic or igneous rocks, the Silurian, Carboniferous, overlying "Red Beds" containing gypsum with some impure limestone referred provisionally to the Triassic, the Jurassic, Cretaceous. A large number of fossils were collected, and descriptions of them by Mr. Whitfield, with a general view of all thus far known from the Black Hills, occupy 135 pages of the volume, and their illustrations 16 of the plates.

The results show that the horizon of the Primordial beds is about the same with that of Wisconsin; that the Subcarboniferous and Permian groups could not be identified, while the Carboniferous is well represented by its mollusks and coals; that the Jurassic beds are full of fossils, as first made known by Hayden's survey in

1857, but have as yet afforded no Gasteropods; that all the formations are conformable to one another from the Cretaceous to the Primordial. The volcanic peaks occur over the part of the Hills north of the parallel of 44° 10′, without any linear arrangement or special relation in distribution. On the northeast margin of the Hills is Bear Butte; on the northwest side, in Red Valley, there are Inyan Kara, the two Sun Dance Hills, Warren Peaks, and another unnamed; on the Belle Fourche, Mato Tepee or Bear Lodge, the three Little Missouri Buttes; within the area, Custer, Terry (the crowning peak of the group), Crow Peaks and Black Butte, besides others less conspicuous. The rock of the cones is mostly sanidin trachytes, partly rhyolitic. No evidence of overflows was found, with a single small exception, as if there had been simply an extrusion of densely viscid material.

The peaks are cones, with sometimes regular craters, and vary in height above the valley at their base, from 300 to 1800 feet. Custer Peak is 675 feet above its base and 6,950 above the sea. Bear Butte is 1,200 feet above its base and only 4,570 above the sea, being about six miles from the edge of the foot-hills. Inyan Kara is 1,300 feet above the bed of the creek of the same name, and 6,600 feet above the sea.

Bear Lodge "is a great rectangular obelisk of coarsely porphyritic sanidin-trachyte, with a columnar structure, giving it a vertically striated appearance, rising 625 feet almost perpendicularly from its base. Its summit is so entirely inaccessible that the energetic explorer, to whom the ascent of an ordinarily difficult crag is but a pleasant pastime, as he stood at its base could only look upward in despair of ever planting his feet on the top." The height above the Belle Fourche is 1,126 feet, and its height above the sea approximately 5,260 feet; the width at bottom is 796 feet and at top 376 feet. In outline it is like the now unfinished Washington Monument. The columns of the columnar trachyte are over 600 feet in length and rise perpendicularly from a seemingly massive base. "It is exceedingly difficult," writes Mr. Newton, "to account for this structure as a result of cooling by comparison with any known basaltic phenomena."

Another remarkable feature of this locality is the undisturbed condition of the surrounding Potsdam sandstone; at a distance of but 50 to 75 feet from the base no evidence of any tilting could be detected, but the sandstone is "converted for some distance into a compact white quartzite."

The Little Missouri Buttes have a height of but 400 to 500 feet. They stand on the Dakota sandstone; but this floor-rock "could not be ascertained to exhibit any disturbance or change of structure due to the proximity of the igneous matter. The rock is greenish-gray trachyte, and there is also at the base, in one or two localities, (what is not mentioned as occurring about the other peaks) an exceedingly light and cellular rock, yellowish in color, very like a volcanic tufa or rhyolite breccia, including fragments of both sandstone and rhyolite.

From these facts the conclusion is arrived at that the time of eruption was later than the Dakota and Fort Benton groups of the Cretaceous and before the Miocene.

The rocks of the Hills were examined microscopically by Mr. J. H. Caswell, whose report occupies the last fifty-five pages of the volume and is illustrated by two colored plates. The report recognizes among the volcanic rocks trachyte, rhyolite, and phonolite, and the rhyolyte-trachyte was under the forms of volcanic glass, pitchstone, pearlstone, spherulite, etc. The trachyte includes sanidin-trachyte and sanidin-oligoclase-trachyte; biotite, hornblende, magnetite and apatite are often present, and the crystals of biotite have sometimes a border of magnetite. The phonolite contains much nephelite and some of it hornblende. The sanidin crystals in the trachyte from the top of Warren Peak are one to two inches long.

The volume contains also chapters on the Mineral Resources and climate of the Black Hills by WALTER P. JENNEY, on the botany, by ASA GRAY, and on the astronomical work of the expedition and the barometric hypsometry, by H. P. TUTTLE.

2. *Primitive Industry, or Illustrations of the Handiwork in Stone, Bone and Clay of the Native Races of the Northern Atlantic Seaboard of America;* by CHARLES C. ABBOTT, M.D. 560 pp., 8vo, Salem, Mass. (George A. Bates.)—Mr. Abbott has done good service to ancient American history in the preparation of this well systematized and well illustrated work. The region which he surveys embraces New England and the States of New York, New Jersey and Pennsylvania; but the wide range of his knowledge enables him to make comparisons with related facts from other parts of the country. Besides treating of implements of stone, bone and clay, the author mentions many examples of implements of copper and describes various shell-heaps—in all his chapters citing freely from previous publications on the subject.

The author's discoveries of flint implements in the stratified drift in the valley of the Delaware near Trenton, and the drift phenomena of the regions east, west and north, are the subjects of the two concluding chapters, the first of them by Dr. Abbott, and the second, on the antiquity and origin of the Trenton Gravel, by Prof. H. C. Lewis, of the Geological Survey of Pennsylvania. Dr. Abbott gives drawings of several of the specimens discovered, describes them as of hard argillite, and more rudely made than the ordinary implements of the country, and regards them as the work of the most ancient race of man on the continent, such as existed here before the disappearance of the ice of the Glacial era —and probably akin to the Eskimo. He refers to the occurrence of a tooth of the Reindeer (Rangifer Caribou), from the Trenton gravels, found by the late Prof. T. A. Conrad; to remains of the same species and of the bison, "in an ordinary rock-shelter" near Stroudsburg, Pennsylvania, along with marks of fire that suggested the idea of a feast on the bison by the men of the time; to the occurrence in New Jersey of antlers of the Greenland Rein-

deer "in the gravel that covers everywhere the older formations" mentioned by Prof. E. D. Cope (Geol. New Jersey, 1868, p. 740); and the long known facts respecting the existence in Kentucky of remains of the Moose, Caribou, Reindeer, Musk Ox and other northern Mammals; and regards Palæolithic man as a resident of the continent in the same era.

Mr. Lewis treats in detail of the stratified deposits of the Delaware, the position of the terminal moraine across the country, the origin of the deposits, and the antiquity of man. His conclusion is that the deposits are apparently post-Glacial, and probably were deposited by the flooded rivers at a period immediately following the last Glacial epoch upon the Delaware river. The view that there was more than one Glacial epoch over the region appears to require more evidence than has yet been presented; and if not a fact the opinion of Mr. Abbott will probably be sustained.

3. *M. E. Wadsworth on the Origin of the Iron Ores of the Marquette District.*—The notice of this paper, on page 320, does Mr. Wadsworth injustice. Its criticisms derived their force in part from the fact stated in the notice that, although the paper mentions the qualifications needed for successful investigation, it contains no "detailed facts, sections, or description of rock-slices," which the qualified investigator should have presented. Since the notice appeared Mr. Wadsworth has drawn my attention to the fact that his memoir "On the Geology of the Iron and Copper Districts of Lake Superior," published over a year ago, contains details of the kind asked for. I had overlooked this, having read and noticed the memoir, soon after its publication, as far as the subject of copper was concerned, but not its earlier half on the iron districts. This is a reason for the oversight but not an excuse for it. I take, therefore, this earliest opportunity to withdraw the derogatory remarks made in this connection. In addition I here transfer to this Journal, from his memoir, the larger part of the section on the "Jasper and Iron Ore," with a portion of his concluding statements. His account of his observations is illustrated by a number of figures showing the relations of the ore, jasper and schists, which are here omitted. He does not, however, give any drawings from microscopic views of thin rock-slices and, as he states, refers to the facts thus observed only in a general way.

I have also here to state that my remark on the banded structure (page 320), does not meet the argument he presents, which aims to show that since banding occurs in both igneous and metamorphic rocks, it cannot be distinctive of either.

With regard to Mr. Wadsworth's method of speaking of the labors and conclusions of others I have nothing further to say.

I add a word here on the bearing of the facts from other Archæan regions, especially those relating to the question of conformability, on the Marquette question, a point not appreciated in Mr. Wadsworth's discussions.

Of all the evidence used to prove a sedimentary origin of the

ore-deposits and schists, that of conformability between them is the one most relied on by geologists, and the most decisive. Mr. Wadsworth has considered it with reference to the Marquette iron ore, and, disagreeing with other observers, has decided the question adversely. But geologists who have studied, with that and other points in view, the widest range of Archæan iron regions—believing that they are alike in mode of origin—have reached the general conclusion that the ore and schists of all, the Marquette included, are conformable in bedding, and hence that they are metamorphosed sedimentary deposits. My own examinations on this point, at localities in New Jersey, New York and Connecticut, have confirmed me in the same view; and, with others, I believe it will be found that any apparent unconformability in bedding is local and a consequence of the disturbances —the flexures, fractures, faultings and attendant changes—which these oldest of beds have undergone. J. D. D.

4. *On the Jasper and Iron Ore of the Marquette Region;* by M. E. Wadsworth.—In the Marquette region, the country rock is of a varying nature, but is mainly composed of schists (largely chloritic), argillites, and quartzite, in that part of the district visited by us. Associated with these rocks is the jasper, which is acknowledged on every hand to be an inseparable part of the iron ore formation. The origin of one gives the origin of the other. Their interdependence is such, and has been so regarded, that the relations of one to the country rock give the relations of the other. The two have been so fully described in the past, that it is only necessary to briefly describe them here.

The common form is that of interlaminations of jasper and iron ore, the laminæ varying from extreme tenuity to considerable thickness. In some places the jasper predominates, in others the ore. In the last case we have a more or less valuable ore, according to the amount of the siliceous material, which, however, may exist only in a mere trace. The purer parts form large masses, that are mined, and which graduate into the jasper, or ore containing so much jasper as to be unfit for working. The workable parts are frequently lenticular in form, although often irregular. The irregularity of the ore mass, its passage into the jaspery ores, and the uncertainty where the next mass will be found, are among the chief difficulties of the miner. The origin of the jasper and ore becomes then a problem of great economic importance, as do also the relations of both to the country rocks. The permanence and extent of the formation, whether it is in the form of vein deposits, eruptive (intrusive or overflow) masses, or sedimentary deposits, are questions in which the capitalist and miner, whether they will or not, are most deeply interested. As they have never been regarded as vein deposits, there remains for us only the question whether the jasper and its associated ores are eruptive or sedimentary in origin.

Lest there be some misunderstanding as to the reason for thus dismissing the theory of the ores here being vein deposits, we

would remark that the question has been ably and fully discussed before in the works of previous observers. Furthermore, while veins on a small scale are occasionally seen, we were unable to find upon either the jasper or its associated ore a single character belonging either to a vein or an infiltration deposit. It therefore seems unnecessary to discuss the vein or infiltration theory here.

As both the eruptive and sedimentary origin of the jasper and the ore have been advocated by some of the most eminent geologists in this country, it is necessary that the question should be answered by the facts, and not by any preconceived theory or idea. The question now is what are the facts, and their most probable explanation. The first and most important thing to be observed in deciding this is the relation of the jaspery formation to its country rocks.

This relation is well shown in and about the Lake Superior mine at Ishpeming. On the north side of one of the abandoned pits just east of the main workings, the junction of the jasper and ore with the chlorite schist was observed and figured. Specimens were also taken that show the contact. The junction of the two is very irregular, the banding of the jasper and ore following the irregularities of this line, while the schist is indurated and its laminæ bear no relation to the line of contact. Stringers of ore project into the schist, which near the jasper is filled with octahedrons of magnetite. The schist loses its green color generally, and becomes apparently an indurated argillite. The contact and relations of the two rocks are not such as are seen when one sedimentary rock is laid down upon another, but rather that observed when one rock is intrusive through another; and in this case the intrusive one is the jasper and its associated ore. On the south side of the same pit the jasper bows in and out in the schist, forming at one place a projecting knob whose banding follows its contour. Lying against it is a long arm of jasper, similarly banded, which ends in a rounded knob. In the southwest corner of the same pit a dike of very fair hematite ore about one foot in width breaks at an angle of 15° across the argillite and schist, whose lamination is vertical. Wherever the unbroken contact of the jasper and ore with the schist could be observed, that junction is seen to be an eruptive one, on the part of the former. At the School-house mine east of the Lake Superior mine, the jasper forms a dike with a knob-like ending, the lamination (banding) following the curvature of the sides. The contacts between the ore and schist were well-marked eruptive ones. Overlying the ore was found on one side a ferruginous and quartzose breccia and conglomerate composed principally of the ruins of the underlying ore and jasper. A similar but finer-grained rock, mostly a quartzite, forms the hanging, or better the fallen wall of the New York mine. This is composed, in like manner, chiefly of the *débris* of the underlying ore and jasper. Mr. Brooks's statement regarding the "quartzite" of the Marquette district is undoubtedly true of this rock, that when he finds the "quartzite," adja-

cent to it will be found all that is left of the ore formation. This, however, is not what Mr. Brooks intended in his statement, as these detrital rocks apparently form but a small portion of his "quartzites." These of course mark old beaches water-worn after the jasper and ore were *in situ*, in nearly their present condition and, if the logic of the geologists of the Michigan and Wisconsin surveys were carried out, these unconformable detrital formations would mark a new geological age. * * *

At the upper portion of the Jackson mine, Negaunee, the jasper and hematite were seen to cut across and obliquely up through the schists. The jasper also curves in a similar manner at right angles to this nearly east and west section. While this could be explained easily by sedimentation, it is fatal to the view of conformable deposition. In pit No. 3 of this mine (Jackson) the ore breaks irregularly through the schist, forming a brecciated-looking mass, while in other cases it runs up into the schist ending in irregular knobs. * * * *

In pit No. 4 a wedge of ore and jasper was seen intruding between and across the lamination of the schist. In the "north pit" the eruptive character of the ore is well shown. Overlying the ore at a low angle is a quartzite containing jasper and ore derived from its underlying ore. At the Home mine in the Cascade range the ore was largely a sandstone impregnated with hematite, strike N. 70° W. with a northerly dip, which varies owing to the contortion of the strata from 30° to 70°. Several dikes of jasper run through this sandstone, in part conforming to the bending of the strata, and in part breaking across the laminæ. There is no mistaking the intrusive character of the jasper and its interlaminated ore here. It is of course almost unnecessary to state that this mine, having as its chief ore a ferruginous sandstone, was long since abandoned. The quartzite (metamorphosed sandstone), which forms the hanging wall of the Pittsburg and Lake Superior mine, Cascade range, has been cut through by dikes and little stringers of nearly pure hematite which, in its present position, is distinctly intrusive. While in general these little dikes follow approximately the bedding, they are seen not to exactly do this, but cut the laminæ obliquely through much of their course. This mine contains as a secondary formation much specular iron. Near the bridge over the Palmer mine the jasper shows well its eruptive character in its junction with the quartzite, while the banding is seen to be parallel to the contact line. This jasper holds in it, and as part of itself, the hematite mined here.

It is advocated by Messrs. Credner and Brooks that all the iron was originally in the state of magnetic oxide, this view being sustained by the crystals of martite found in various parts of the district.

It would seem that a microscopic examination of the banded jasper and ore should give us some facts bearing upon the question. A section was made of a finely-banded jasper taken near

the Lake Superior mine. Under a lens this shows a fine contorted banding. Microscopically this section is composed of a fine granular aggregate of quartz and hematite, and a more coarsely crystallized portion made up of octahedrons of magnetite or martite, and of quartz of secondary origin. The quartz in the first part is largely filled with minute globules and grains of ore, which also occurs in irregular masses and in octahedrons. The quartz associated with the more coarsely crystallized portion is water clear, and shows the usual fibrous granular polarization of secondary quartz. Wherever the iron is in a distinguishable crystalline form it is in octahedrons. The color and streak of the iron in the hand specimen are those of hematite, but the powder is found to be magnetic. The section was taken from the most jaspery portion, and shows much of the fine aggregation of quartz and hematite. The structure of the quartzose portion is like the devitrification structure of the rhyolites and felsites. The section has been repeatedly fissured, and the fissures filled in with secondary deposits of quartz and octahedral crystals of iron. So far as we have observed, the brecciated jasper and ore have had their fractures filled in like manner. The jaspery portion is finely banded, and shows an apparent fluidal structure. We are inclined to regard the structure as fluidal, but in a rock so deeply colored it is difficult to make satisfactory examinations. This is the only section that shows anything like a well-defined limit between the jasper and ore bands, under the microscope, as pointed out by Dr. Wichmann.* The powder of the two last-described specimens is feebly magnetic. The quartz is much fissured, showing the effect of heat, and contains microlites and fluid and stone inclusions.

The octahedral form of the iron ore would sustain the view that it was all originally magnetite. The difficulty lies in proving the crystals to be primary, and not secondary forms, especially as they are largely associated with secondary quartz, and also are abundant in the little fissures (minute veins), traversing the jasper. Our microscopic examination of rocks of various ages and characters goes to show that all rocks, especially the older, have been subject to more or less alteration. This alteration is accompanied by recrystallization, which often obliterates the original characters. This change appears to be produced through the medium of the percolating waters, and consists rather in a chemical rearrangement of the constituents of the rock, amongst themselves, than in the deposition of any material brought in from extraneous sources. The jasper and iron ores, as well as all other rocks examined microscopically from this district, have suffered this alteration to a greater or less extent; therefore it is perhaps impossible at present to be sure of the original state of the iron, or how many changes have taken place.

Without objecting in any degree to the idea that the ore was originally magnetic, certain facts indicate that the present mag-

* Geol. of Wisc., iii, 615.

netic state of the iron is in some places due to secondary causes; i. e. the heat of intrusive rocks erupted since the iron ore and jasper were in place. While in general the Republic Mountain ore is hematite, exceptions exist. On the northerly side of the hill a "diorite" dike was seen. It is found that the ore was so affected by the heat of this intrusive mass that it is magnetic adjacent to it, while a short distance away it is the normal hematite. Numerous other localities were examined about the hill where these secondary intrusions occurred, with the same result; the iron ore was magnetic adjacent to the dikes, but not magnetic a short distance away. As a general rule, the magnetite or the hematite pseudomorphs after it (martite) are found near the "quartzite" of Brooks in this mine. Those who examine the map of Republic Mountain, prepared by him,* will observe on the northern side of his "quarztite," a queer tongue of it projecting into the hematite. An examination of this tongue at different places shows the following facts: It contains numerous rounded and irregular fragments of the iron ore in it; these fragments occur on both edges, while the centre of the mass is free from them. At this point it varies from a few inches to two feet in width, and it is seen to break across the lamination, although nearly coinciding with it. At another part shown near the same pit, this rock and its contact with the "jasper" and ore were well marked. The "quartzite" is firmly welded to the ore, and breaks across the laminæ, cutting them, and sending tongues into the mixed jasper and ore. The junction is an eruptive (intrusive) one, and not that belonging to the contact of one sedimentary rock with another. The ore at the junction is magnetic. The question whether this is an intrusive or sedimentary rock has another side than the simple scientific one. It makes a great difference in the mine whether this is a simple overlying metamorphosed sandstone, as Mr. Brooks places it, or a later intrusion cutting the ore below. This latter case opens up numerous questions that the practical man can only disregard to his cost, sooner or later, but which have nothing to do with the present discussion.

As this rock seems to belong to the granites, it will be described under them. Should future research show that all of the "quartzite" of Republic is the same as the tongue is, it would have a bearing on the proximity of the magnetite and martite to it.

In like manner, passing to other mines where secondary intrusions are more abundant, the magnetite becomes a more prominent feature. It seems, so far as we have seen, that the magnetite and martite are directly proportioned to the amount and proximity of eruptive rocks, extravasated since the ore was *in situ*.—*Geol. Iron and Copper Districts*, pp. 28–35.

From the "General discussion," in the last chapter, on the Iron District.—So far as geological science has now advanced,

* Atlas, Geol. of Mich., 1869–73, Plate VI.

the facts observed can only be explained by the eruptive origin of both the ore and jasper, as they make the same formation.

The ore and jasper show that they are the intrusive bodies by their breaking across the lamination of the schists and other rocks, by the changes that take place in the latter at the line of junction, by horses of schist being enclosed in the ore, by the curvature of the lamination, produced by the intrusion of the ore and jasper, etc. Not the slightest sign of the plasticity or intrusion of the schists relative to the ore or jasper was seen. That the present lamination of the schist existed prior to the intrusion of the ore and jasper is shown by the effect of the latter upon and its relations to it. That this lamination is the original plane of deposition is for part of the schists not known; but whether it is or not, it has been taken to be such by the observers quoted in the establishment of their theories, and they must abide by it. The lamination, however, coincides with many of the well-stratified rocks adjacent, and in some of these the ore and jasper were unmistakably intrusive. The schists that retained well-marked stratification planes showed in some places extraordinary contortions, one specimen showing a synclinal and anticlinal fold, requiring, were the top eroded, the counting of the same layer four times in the width of two inches. This is only one case out of numerous ones observed.—*Ibid*, p. 67.

5. *Saurian and Mammals of the Lowest Eocene of New Mexico.*—Professor Cope has described in the American Naturalist (August, 1881), a Saurian, *Champsosaurus australis* Cope, from beds in New Mexico which lie below the typical Wasatch Eocene, and possibly from the Puerco beds. The genus was first described by Cope from specimens in the Laramie beds named *C. laticollis*, and has since been recognized by Dr. Lemoine, near Reims, in the Suessonian Eocene associated with mammals. From these same lowest Eocene beds of New Mexico Prof. Cope has described the mammals, *Mesonyx Navajovius* (Creodont), *Periptychus carinidens* (Creodont), *Triisodon Quivirensis* (Creodont, which group is placed by the author between the Marsupials and Carnivores), *Deltatherium fundaminis* (Creodont), *Conoryctes comma*, allied to Mesonyx, *Catathlæus rhabdodon*, *Anisonchus sectorius*, *Mioclænus turgidus*, *M. subtrigonus*, *Phenacodus Puercensis*, *Ph. Zuniensis*, *Protogonia subquadrata* (Chalicotheriidæ), *Meniscotherium Terrærubræ*. No Coryphodon remains have yet been detected in the beds. The Suilloid genera are stated to be characteristic.

6. *Miocene Rodents of North America and Canidæ of the Loup Fork Epoch.*—A review of the N. A. Miocene Rodents and another of the Canidæ of the Loup Fork Epoch is published by Professor Cope in vol. vi of the Bulletin of the U. S. Geol. Survey under Dr. Hayden, for September, 1881.

7. *The Irish Elk, Megaceros Hibernicus, in the Ancient lake deposits of Ireland.*—Mr. W. Williams, in the Geological Magazine for August, describes the deposits of some of the bogs of Ire-

land, with reference to the position in them of bones of the Irish Elk. Those of the Ballybetagh bay, about nine miles southeast of Dublin, have first (1) a lining of tenacious clay resting on bowlder clay, within this at bottom (2) a yellowish gray bed, slightly clayey, consisting chiefly of vegetable matter; next (3), a bed of dark brownish clay containing remains of Megaceros; then (4), a grayish clay about thirty inches thick, containing rock debris from the hills; which last is covered by peat. He states that the bones are found only in No. 3, and that during the thirty years past, nearly one hundred heads have been found in this bog (almost all males), with scarcely six skeletons. The stage of growth of the antlers—whose average weight is sixty pounds—shows that the animals were mired at different times during the year.

The clay No. 4 is regarded by the author as having been deposited during the second Glacial epoch, and the stones it contains are attributed to the ice and frosts of that time. In this clay the author found the antler of a Reindeer, and this is regarded as corroborative of his conclusion. The broken state of the bones of the Megaceros is attributed to the pressure of the overlying mass or masses of ice. No human implements occur in the clay, leading to the conclusion that "man had hardly appeared in Ireland," and that the Megaceros was exterminated not by man, but by the augmenting cold of the approaching Glacial era. All these inferences are stated to be sustained by the facts from other Irish bogs.

8. *The Tertiary Lake Basin of Florissant, Colorado;* by S. H. Scudder. pp. 279–300 of the Bulletin, vol. vi, No. 2, of the U. S. Geol. and Geogr. Survey, under Dr. F. V. Hayden (Dept. of the Interior).—Mr. Scudder describes in this paper the position, characters, paleontology and age of the remarkable lacustrine deposits of Florissant, Colorado, and illustrates the subject with a map. His observations in the region were made in 1877, along with Mr. A. Lakes, whose geological notes are incorporated, and also Mr. F. C. Bowditch. The lake-basin, nearly nine miles long, according to the map, occupies a low depression among the mountains at the southern extremity of the Front Range of Colorado "at no great distance from Pike's Peak," and sends its arms up the valleys on either side. The beds are whitish, drab and brownish shales below, with fine and coarse sandstone above; and, besides, trachyte occurs in the adjoining promontories and along the margin of the basin. The material of the coarser beds directly above the shales, from a locality visited by Mr. Scudder (south of the house of Mr. A. Hill), according to microscopic investigations by Mr. M. E. Wadsworth, is tufaceous; and the shales are "simply the finer material of the tufas laid down in laminæ of varying thickness and coarseness." The shales at this place are about 22½ feet thick. The fossils from the Florissant shales include:—of Hymenopterous insects, several species of Apidæ and Andrenidæ, about 30 of Vespidæ or wasp-like Hymenoptera, 50 species or more of ants (mostly Formicidæ, with

some Myrmicidæ and Poneridæ) represented by about 4,000 specimens; about 80 species of Ichneumonidæ, over 100 other species of Hymenopters; of Lepidopters perhaps a dozen species; of Dipters, some thousands of specimens and a large number of species, among them 1,000 specimens of Bibionidæ, and "a vast host of Muscidæ and allied kinds;" of Coleopters, over 300 species, of the normal series, and about 120 of the Rhyncophorous section; of Hemipters, more than 100 species of the Heteroptera, and 65 of Homoptera; of Orthopters, many species; of Neuropters, largely the Phryganidæ of which there are 15 or 20 species, 6 species of the Termites family, and others; of Spiders, 30 species, all Araneæ; one Myriapod, an Iulus; of Mollusks, only one species, that a Planorbis; of Fishes, 8 species, all described by Cope, except one by Osborn, Scott and Speir; of Birds, several feathers, a single tolerably perfect Passerine bird, described by J. A. Allen, under the name *Palæospiza bella*, and a plover, *Charadrius Sheppardianus*, described by Cope.

The fossil plants include large silicified trunks of trees probably Sequoias, and many species, 90 to 100 in all, about 40 of which have already been described by Lesquereux, besides some flowers with long stamens. The assemblage of plants indicates, according to Lesquereux, a climate like that of the northern shores of the Gulf of Mexico; of fishes, according to Cope, of latitude 35°; of insects, according to Scudder, a still warmer climate.

The age of the deposits is referred by the most recent and best authorities to the later Eocene or early Miocene.

The insects are soon to be desbribed by Mr. Scudder in a quarto volume and illustrated by a large number of plates.

9. *Address of the President of the Geological Society of London*, Robert Etheridge, F.R.S., at the Anniversary Meeting on the 18th of February, 1881.—The subject of this address, is the "Analysis and Distribution of the British Paleozoic Fossils." It is a carefully prepared and critical review of what has been learned respecting the ancient life of Great Britain in Paleozoic time, drawn up with details as to the species of plants and animals in the successive formations, and as to their stratigraphical and geographical distribution, and it has a special interest for the American geologist, on account of the wide extent and thickness and abundant fauna of related rocks on this side of the Atlantic.

10. *Pantotheria of Marsh.*—This word is incorrectly spelled *Prototheria* on page 286 of this volume.

11. *Occurrence of Vanadates of Lead at the Castle Dome Mines in Arizona;* by Wm. P. Blake.—The occurrence of various vanadium minerals at different points in Arizona has been recently described by Professor Silliman in this Journal. Similar observations were communicated to the Mining and Scientific Press of August 13, by Professor Wm. P. Blake. He states that vanadinite occurs in considerable abundance at the "Railroad" claim in the Castle Dome district. It forms groups of small hexagonal prismatic crystals, generally curved and tapering as is common in pyromorphite. It is also found in

crusts of confusedly aggregated crystals, sometimes filling cavities in decomposing ores of lead and sometimes fluor-spar. The color of the larger crystals is generally brown; the smaller ones are lighter and are of various shades of orange, yellow, and yellowish-brown, the latter of a wax-like luster. Associated with the vanadinite are possibly some rarer vanadates, not yet identified, wulfenite, in brilliant light-yellow crystals, and a vanadiferous mimetite which seems to graduate into the pure vanadinite. Professor Blake also mentions the occurrence of beautiful crimson-red crystals of vanadinite from the Hamburg mine and fine wulfenites, sometimes in octahedral crystals, from the Red Cloud mine, the "Oakland Boys' claim," and other points in the Silver District, Arizona.

III. Botany and Zoology.

1. *Recent papers on the Marine Invertebrata of the Atlantic coast of North America;* by A. E. Verrill.—During the past few years a much more active interest has been taken in the marine invertebrata of our coast than ever before, and accordingly there has been a rapid increase in the number of papers published on this subject. This has been due principally to the extensive explorations of the sea-bottom and its life, made by the U. S. Coast Survey and the U. S. Fish Commission. The work done by the Coast Survey was mostly in the southern waters, in the Gulf of Mexico, Carribbean Sea, and off Florida, but in 1880, included lines of dredging off the eastern coast of the United States, and even to the region off George's Banks. This work, so well begun by Pourtales, has, during the later years, been carried on with great perseverance, and with remarkable success by Mr. A. Agassiz, whose collections, made by the steamer "Blake" are of wonderful extent and interest. Numerous reports on the earlier of these collections have been published, during past years, but in the following list, I include only the more recent ones.

The explorations by the U. S. Fish Commission, under the supervision of the writer, have been mostly along the northern coast, from Long Island Sound to Nova Scotia, and in water of moderate depths, usually within 100 miles of the coast. But all this region has been very fully examined, dredgings having been made at over 1600 stations, while collections of very great extent have been accumulated. As yet very few of the final reports on these collections have been published, but numerous preliminary papers, by the writer and others, have been printed. Among the more recent papers relating to the Fish Commission collections, in addition to those printed in this Journal, are the following:

Report on the Marine Isopoda of New England and Adjacent Waters. By Oscar Harger. <*Report of the United States Commission of Fish and Fisheries*, Part VI, for 1878 [pp. 297–458, 13 plates], 1880.—This is a complete monographic report on all the species (46) known up to the date of publication, with descriptions and good figures of nearly all the species. It is followed by a bibliographical list of works on the subject.

Report on the Pycnogonida of New England and Adjacent Waters. By EDMUND B. WILSON. <*Report of the United States Commission of Fish and Fisheries*, Part VI, for 1878 [pp. 463–504, pl. 1–7], 1880.—A monographic revision of all the species—fifteen in number—followed by a bibliographical list.

Notice of a new Species [*Polycheles sculptus*] *of the "Willemoesia Group of Crustacea,"* (*Recent Eryontidæ*). <*Proceedings U. S. National Museum*, vol. ii, for 1879, [pp. 345–353, pl. 7], March, 1880. By SIDNEY I. SMITH.

Preliminary notice of the Crustacea dredged in 64 to 325 fathoms, off the south Coast of New England, by the United States Fish Commission in 1880. By S. I. SMITH. <*Proceedings U. S. National Museum*, vol. iii, for 1880, [pp. 413–452], January, 1881.—Contains a general list of fifty species, with their geographical distribution and descriptions of numerous new species and one new genus (Hemipagurus).

Notice of Recent Additions to the marine Invertebrata of the northeastern coast of America with descriptions of new genera and species and critical remarks on others. <*Proceedings of the United States National Museum*, vol. iii, Dec., 1880, and Jan., 1881.

Part II.—Mollusca, with Notes on Annelida, Echinodermata, etc., collected by the U. S. Fish Commission [pp. 356–405], Dec., 1880 and Jan., 1881.

Part III.—Catalogue of Mollusca recently added to the Fauna of Southern New England [pp. 405–409]. By A. E. VERRILL.

The Cephalopods of the Northeastern Coast of America. By A. E. VERRILL. *Part II.—The smaller Cephalopods, including the "Squids" and Octopi, with other allied forms.* <*Trans. Conn. Acad.*, v, [pp. 259–424 (unfinished), pl. 26–56], June, 1880, to Oct., 1881.—Although this paper is all in type, a few of the last signatures are not yet issued. It is a monographic revision, with descriptions and figures of all the species. A considerable amount of anatomical work is also introduced. Most of the species have already been noticed by me, in different articles, in this Journal. Among those not previously described are *Chiroteuthis lacertosa*, *Brachioteuthis Beanii*, gen. et sp. nov., *Rossia megaptera*. *Brachioteuthis* is a deep-sea genus, allied to *Chiroteuthis*, but having simple connective cartilages on the siphon and mantle. A new genus (*Stoloteuthis*) has also been established for *Sepiola leucoptera* V. It is remarkable for having *free* eye-lids, round pupils, arms webbed, and no pen. *Inioteuthis* is established for *Sepiola Japonica;* it differs from *Sepiola* in lacking a pen. A second Japanese species has four rows of suckers (*I. Morsei*).

New England Annelida. Part I, Historical Sketch, with Annoted Lists of the Species hitherto Recorded. By A. E. VERRILL. <*Trans. Conn. Acad.*, iv [pp. 285–324], 1881.—In connection with the annotation, a considerable number of changes in nomenclature are introduced, and a few new genera are established. These are *Euglycera* for Glycera dibranchiata Ehlers; *Dipoly-*

dora, for Polydora concharum V.; *Praxillella* for Praxilla (preoccupied). The several species hitherto referred to Anthostoma are referred to *Scoloplos*.

The following papers relate to the collections made by Mr. Agassiz, on the "Blake:"

Reports on the Results of Dredging, under the supervision of Alexander Agassiz, by the United States Coast Survey Steamer "Blake." Bulletin of the Museum of Comparative Zoölogy, Vols. viii, ix.

VIII.—Etudes préliminaires sur les Crustacés. Par A. Milne-Edwards. *I*er *Partie*, viii, [pp. 1–68, 2 pl.], Dec. 29, 1880.—Contains brief descriptions of a large number of new genera and species of Decapoda. Many of them can scarcely be identified without figures.

IX.—Preliminary Report on the Echini. By A. Agassiz. Vol. viii, [pp. 69–84], Dec., 1880.—Enumerates 45 species, of which many are described as new.

X.—Report on the Cephalopods, and on some additional species dredged by the United States Fish Commission Steamer "Fish Hawk," during the season of 1880. By A. E. Verrill. Vol. viii, [pp. 99–116, 8 plates], March, 1881.—This includes descriptions of two new species, viz: *Mastigoteuthis Agassizii*, gen. et sp. nov., *Eledone verrucosa*. Figures and descriptions are also given of Chiroteuthis Bonplandi? [=*C. lacertosa* V., 1881], Rossia sublevis, Heteroteuthis tenera, Octopus Bairdii, O. lentus, Cheloteuthis rapax V. [=Lestoteuthis Fabricii V. [=Gonatus Fabricii Steenst.], Calliteuthis reversa, Alloposus mollis.

XI.—Report on the Acalephæ. By J. W. Fewkes. Vol. viii, [pp. 127–140, 4 plates], March, 1881.—Contains descriptions of several new species of *Plumularidæ*, *Sertularella*, *Lafoëa*, and of a new genus, *Aglaophenopsis*.

XIII.—Report on the Pycnogonida. By E. B. Wilson. Vol. viii, [pp. 239–256, 5 plates], March, 1881.—Ten species are recorded. One genus and five species are new. The new species belong to *Colossendeis*, *Scævorhynchus* (nov.), and *Pallenopsis* (nov.) Some of the species of *Colossendeis* are of great size (extent, 343mm).

XV.—Preliminary Report on the Mollusca. By W. H. Dall. Vol. ix, [signatures 3–6, pp. 33–96, unfinished], July to September, 1881.—A large number of new species and several new genera are described in the four signatures received. Among the genera treated are Cadulus, Dentalium, Siliquaria, Pedicularia, Margarita, Calliostoma, Seguenzia, Basilissa, Septothyra, Callogaza, nov., Microgaza, nov., Fluxina, nov., Hanleyia, Pleurotoma and its subdivisions, Trichotropis, Marginella, Puncturella, Pleurotomaria, Haliotis, Crepidula, Triforis, Cerithiopsis, Bittium, Columbella, Natica, Turritella, Actæon.

XVI.—Preliminary Report on the Comatulæ. By P. Herbert Carpenter. Vol. ix, [20 pp. 1 pl.], Oct. 1, 1881.—The author states that he now recognizes about 55 species of this group from the Caribbean Sea and West Indies. They belong

mostly to the genera *Actinometra* and *Antedon*. Of these the former is the more abundant, both in species and individuals. In this paper a few new species of these genera are described, and two species of a new genus, *Atelecrinus*. The "Blake" collection is contrasted with that of the "Challenger."

Various other papers, not relating particularly to the two explorations referred to above, have been recently published. Among these are the following:

The Stomach and Genital Organs of Astrophytidæ. By T. LYMAN.<*Bull. Mus. Comp. Zoology*, viii, [pp. 117–126, 2 plates,] Feb., 1881.

Studies of the Jelly-Fishes of Narragansett Bay. By J. W. FEWKES.<*Bull. Mus. Comp. Zoology*, viii, [pp. 141–182, 10 pl.]. —This includes many details concerning several known species and the following new forms: Mabella gracilis, gen. and sp. nov., Modeeria multitentacula, Dinematella cavosa, gen. and sp. nov., Eutima gracilis, Sphærula formosa, gen. and sp. nov., Cunina discoides.

II.—The Siphonophores. The Anatomy and Development of Agalma (continued). By J. WALTER FEWKES. <*American Naturalist* [pp. 186–195], March, 1881.

On some Points in the Structure of the Embryonic Zoëa. By WALTER FAXON.<*Bull. Mus. Comp. Zoology*, vi, [pp. 159–166, 2 plates], Oct., 1880.—Relates to the development of *Carcinus* and *Panopeus*.

On some Crustacean Deformities. By W. FAXON.<*Bull. Mus. Comp. Zoology*, viii, [pp. 257–274, 2 plates.]—Discusses numerous deformities of *Homarus* and *Callinectes*.

The Development of the Squid, Loligo Pealii (Lesueuer). By W. K. BROOKS.<Anniversary Memoirs of the Boston Society of Natural History, 1880.

Annelida Chætopoda of New Jersey. By H. E. WEBSTER. <*Thirty-second Annual Report on the New York State Museum of Natural History*, [pp. 1–28, *plates not issued*] 1880, (*dated* 1879).—Although put in type in 1879, this paper was not actually published until 1880, and the plates that were prepared for it have not yet been published. A number of new species are described belonging to the genera Anaitis, Eteone, Podarke, Grubea, Goniada, Polydora, Streblospio (gen. nov.), Praxilla, Paraxiothea (gen. nov.), Sabellides. Fifty-nine species are enumerated.

2. *A Manual of Practical Normal Histology;* by T. MITCHELL PRUDDEN, M.D. (New York: G. P. Putnam's Sons, 1881.) pp. viii and 265, small 8vo.—The method of giving a brief description of the tissues and organs in appropriate sequence, and following each description with an account of the way in which the structures described may be demonstrated has been admirably carried out in this modest little volume, which well fills an unoccupied place among elementary text books. In no other English text book certainly can be found so concise and clear an account of the structure of the principal animal tissues, as at present understood. The directions for demonstration are sufficiently

simple and clear to be readily followed, even without an instructor, by any intelligent student familiar with the use of the microscope. S. I. S.

3. *U. S. Entomological Commission, Department of the Interior.* Index volume to Dr. Riley's Missouri Reports on Insects.—Bulletin No. 6 of this Commission, numbering 178 pages, 8vo, consists of a General Index and Supplement to the Nine Reports by Charles V. Riley, M.A., Ph.D., on the Insects of Missouri. The importance of these reports, economically and scientifically, makes this Index volume one of much value. It is intended to stand as vol. x of the series. To increase the value of the volume, the author has brought together the tables of contents of the nine volumes, with errata, and has also reproduced the descriptions of new species, added a list of descriptions of adolescent states, of descriptions of species not new, of food plants, and of illustrations.

4. *The Hessian Fly, its ravages, habits, enemies, and the means of preventing its increase*, by Dr. A. S. Packard, is the subject of Bulletin No. 4. It is illustrated by a map and two plates.

5. *E. S. Morse on changes in Mya and Lunatia.*—Professor Morse has sent the following correction for his note on page 323 of this volume: "A comparison of the common beach cockle Lunatia showed that the present form living on the shore to-day had a more depressed spire than the ancient form."

IV. Astronomy.

1. *Theory of the Moon's Motion, deduced from the Law of Universal Gravitation*; by John N. Stockwell, Ph.D. Philadelphia, 1881. (J. B. Lippincott & Co.)—Although the motion of the moon around the earth has been the subject of profound study, during the past two hundred years, and has been the occasion of more elaborate mathematical investigations than all the other members of the solar system together, the tables of the moon's motion which are based on these calculations fail to represent the moon's place in the heavens with a precision at all commensurate with the labor bestowed upon the lunar theory. As a matter of fact the latest tables of the moon scarcely represent the observations with greater precision than those in use at the beginning of the present century. In view of this fact, the author of this work several years since called the attention of astronomers to the great apparent errors of the lunar theory, and expressed the belief that the theory itself must be in error by terms of the third order of magnitude in the perturbations, instead of being correct to terms of the seventh order, as had been hitherto supposed.

In order to satisfy himself of the correctness of this conclusion, he undertook, some six years ago, a complete and systematic development of the lunar theory, according to a method different from any that had been before applied to the problem. The

application of this method to the motion of the moon constitutes the principal, or strictly technical part of the work; while the history of the problem and the comparison of the results obtained, with the corresponding results of other calculators, is given in considerable detail in the introduction.

The author believes that he has discovered two equations of the third order of magnitude having a short period, besides other terms of long period depending on the sun's action and on the oblateness of the earth, which have not been before correctly computed, and which are of very considerable importance in the lunar theory. Should these results be confirmed by other calculators, the remark of the late Astronomer Royal, Sir G. B. Airy, made some eight years ago, namely: "that there is some serious defect in the lunar theory," will be fully justified.

This is the first book published in this country, which is wholly devoted to the mathematical development of the *general theory* of the moon's motion, as affected by the sun's attraction; although important papers have been published at different times in the various scientific journals of the country, upon some particular cases of lunar perturbation due to the sun's action. The problem, though old, is still one of the most interesting and important in celestial mechanics; and it is to be hoped that other American mathematicians will interest themselves in its solution.

The book contains about *four hundred* pages, and in this respect contrasts happily with the great works of Plana and Delaunay, which, taken together, cover considerably more than *four thousand* pages.

It is printed in handsome style, on excellent paper. Aside from the intrinsic importance of the subject of which it treats, it furnishes a multitude of beautiful solutions of problems which are always of interest to the student of the pure mathematics; and we cordially commend it as worthy of a place in all the scientific libraries of the country, whether public or private.

2. *Astronomical and Meteorological Observations made during the year* 1876 *at the U. S. N. Observatory.* Rear-Admiral C. H. Davis, Superintendent. Government Printing Office, 1880.—This contribution of the Naval Observatory to science fills two thick quarto volumes, one containing the regular observations and the other made up of three important appendices. The first appendix is a subject index (of 74 pages) prepared by Prof. Holden, to all the publications of the U. S. N. Observatory. It makes the valuable material that is scattered through these volumes far more easily accessible than heretofore to astronomers. The second appendix (of 126 pages) contains the several reports on the transit of Mercury, in May, 1878. The third appendix, on the solar eclipse of July, 1878, has been already noticed (this Journal, III, vol. xxi, p. 334). H. A. N.

OBITUARY.

Dr. G. Linnarsson, paleontologist of the Geological Survey of Sweden, died recently at the age of forty years.